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High Resolution Infrared Spectroscopy of Carbon Dioxide and Nitrous Oxide at Elevated Temperatures

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The AFGL High Resolution Interferometer has been used in conjunction with a high temperature absorption cell to make spectral measurements on CO_2 and N_2O. This study includes the identification of over 11,000 molecular transitions belonging to 78 different rotation-vibration bands of CO_2 and over 4100 lines belonging to 18 bands of N_2O. Many of the high J transitions for these bands have not been observed previously. A weighted least-squares-fit technique was then used to obtain new effective molecular constants for each of these bands.

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Preface

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High Resolution Infrared Spectroscopy of Carbon Dioxide and Nitrous Oxide at Elevated Temperatures

1. INTRODUCTION

Although both CO_2 and N_2O are minor constituents of the terrestrial atmosphere, they play leading roles in several current atmospheric problems. Both CO_2 and N_2O are greenhouse gases, and while it is known that the atmospheric concentrations of both gases is increasing,[1,2] the impact of these trends on global temperature is not yet adequately understood.[3] In addition to being a greenhouse gas, N_2O plays an indirect part in ozone chemistry.[1,4,5]

In addition to the direct knowledge gained by studying the high temperature spectra of gases, these studies help increase the general understanding of the

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(Received for publication 2 March 1988)

1. Hudson, R.D. and Reed, E.I. (1979) The Stratosphere: Present and Future, NASA Report 1049
2. Weiss, R.F. (1981) The temporal and spatial distribution of tropospheric nitrous oxide, J. Geophys. Res., 86(C8):7185-7195.
3. Wang, W.C., Yung, Y.L., Lacis, A.A., Mo, T., and Hansen, J.E. (1976) Greenhouse effects due to man-made perturbations of trace gases, Science, 194(No. 4266):685-690.
4. Crutzen, P.J. (1971) Ozone production rates in an oxygen, hydrogen, nitrogen-oxide atmosphere, J. Geophys. Res., 76:7311-7327.
5. World Meteorological Organization, Global Ozone Research and Monitoring Project, WMO Report No. 16 (1985).

physics of molecules.[5] Heating a molecule makes possible the observations of molecular transitions originating from highly excited rotation-vibration states. These observations can then be used to characterize the shape of the molecular potential function at increasing distances from the minimum of the potential function.

The infrared spectra of linear molecules like CO_2 and N_2O are composed of vibration bands made up of a number of nearly equally spaced rotation lines. At high temperatures, there is a great deal of overlapping of these bands. This overlapping causes two main problems. First, the line density in the experimental spectrum becomes very high, requiring high spectral resolution. Second, this overlapping masks the regular structure of each band, complicating line assignment. To assign lines, it is very helpful to have wide continuous spectral coverage so that entire band systems can be observed. A Fourier Spectrometer is ideally suited to the study of high temperature gases since it meets both of these needs by providing high resolution over a wide spectral region.

The AFGL high resolution Fourier Spectrometer has been used to carry out an ongoing study of atmospheric gases at elevated temperatures. This report summarizes the results that have been obtained during the present reporting period. Spectra were recorded of N_2O and three different isotopic species of CO_2 in several different wavelength regions. The observed lines in the experimental spectra were then identified with individual molecular transitions for as many molecular transitions as possible (over 12,000 transitions). The final step was to use a least-squares fit to calculate new effective molecular constants.

2. THEORETICAL BACKGROUND

From a fundamental point of view, CO_2 and N_2O possess similar physical properties. Both CO_2 and N_2O are linear, triatomic molecules. They are isoelectronic[6] and have a nuclei of nearly equal charge and mass. Only the electronic ground state of either molecule is significantly populated in the present experiment, yet its configuration plays an important role in determining the rotation-vibration energy levels. This occurs through the coupling of the electronic spin or orbital angular momentum to the motion of the nuclei. However, in the ground electronic state of both CO_2 and N_2O the net orbital and spin angular momenta of the electrons are zero, so there is no net electronic angular momentum to couple with the motion of the nuclei. There is a Fermi resonance between the bending mode, $2\nu_2$, and

6. Bowens-Jenkins, P.E., Cooper, D.L., and Richards, W.G. (1985) Ab initio computation of molecular similarity, J. Phys. Chem., 89(No. 11).

the symmetric stretching mode, ν_1, in both molecules.[7] Coriolis interactions and l-type doubling also occur for both molecules. The Coriolis interaction[8] occurs because as the molecule rotates, the asymmetric stretching mode ν_3 becomes coupled with the bending mode ν_2. For vibrational bands where the l-type doubling interaction occurs, each rotation-vibration energy level splits into two levels; an "e" level with a symmetric wave function, and an "f" level with an antisymmetric wave function. The degeneracy of the e and the f energy levels is removed by the rotation of the molecule.

In several respects, however, CO_2 differs from N_2O. The main difference between the two molecules is the symmetry. CO_2 has a symmetric structure O-C-O where the N_2O structure is asymmetric N-N-O. These symmetry differences greatly affect the nature of the spectra. Due to the symmetry of the CO_2 molecule, transitions involving the symmetry stretch mode, ν_1, are not dipole allowed. In addition, alternating lines are missing from rotation-vibration transitions (they have zero statistical weight). If both of the oxygen atoms in the CO_2 molecule are not of equal mass, the symmetry of the molecule is broken and the character of the spectrum becomes more like that of N_2O. This study covered both the symmetric isotopic species $^{12}C^{16}O_2$, $^{13}C^{16}O_2$, and $^{12}C^{18}O_2$ and the asymmetric species $^{12}C^{16}O^{18}O$, $^{13}C^{16}O^{18}O$, and $^{13}C^{16}O^{17}O$.

The rotation-vibration energy term values, T(v, J), of a linear molecule can be expressed as a power series in J(J + 1), that is

$$T(v, J) = G_v + B_v J(J+1) - D_v[J(J+1)]^2 + H_v[J(J+1)]^3 + L_v[J(J+1)]^4 \qquad (1)$$

where G_v, B_v, and so on, are effective molecular constants. Each line in the experimental spectra corresponds to the transition between a pair of rotation-vibration states. For those bands where l-type doubling occurs ($l > 0$) two sets of effective molecular constants are used, one for the e levels and the other for the f levels.

The notation of the vibrational states that were used for N_2O and CO_2 is different. For N_2O the notation was $v_1 v_2 l v_3$. For CO_2 the AFGL notation[9] was used.

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7. Tidwell, E.D., Plyler, E.K., and Benedict, W.S. (1960) Vibration-rotation bands of N_2O, J. Opt. Soc. Am., 50(No. 12):1243.

8. Herzberg, G. (1945) Molecular Spectra and Molecular Structure, Vol. II, Van Nostran Reinhold, New York.

9. McClatchey, R.A., Benedict, W.S., Clough, S.A., Burch, D.E., Calfee, R.F., Fox, K., Rothman, L.S., and Garing, J.S. (1973) AFCRL-Atmospheric Absorption Line Parameters Compilation, AFCRL-TR-73-0096, AD 762904.

In the AFGL notation the vibrational states are identified by $v_1 v_2 l v_3 r$, where "r" is the ranking index assigned to each member of a Fermi resonating group of levels. When a state is not involved in Fermi resonance, r = 1 and the AFGL notation is essentially the same as the notation used for N_2O. When Fermi resonance is present the ranking index, r, is appended to the quantum numbers of the interacting state with the highest v_i. For example, the AFGL notation for the two states 10^00 and 02^00, which are highly mixed by Fermi resonance, is 10001 and 10002.

3. MEASUREMENTS PERFORMED

The Air Force Geophysics Laboratory high resolution interferometer was used in conjunction with a high temperature absorption cell to make the spectral measurements. The N_2O and CO_2 samples that were used in the study were heated to temperatures up to 800 K. The N_2O spectra were taken in the 8 μm region using a N_2O sample of natural isotopic abundance. The CO_2 spectra were taken in the 2.8 μm and 4.3 μm regions. Three different isotopic samples of CO_2 were used, a sample of natural isotopic abundance, a sample enriched in ^{13}C, and one enriched in ^{18}O. As parts of this work have been completed, the results have been incorporated into two previous AFGL Technical Reports.[10,11] Table 1 gives a summary of where these results, including line positions, can be found for each molecule and spectral region. These results have also been published in The Journal of Molecular Spectroscopy.[12,13] In addition, the information on line position of CO_2 have been incorporated into the 1986 edition of the AFGL HITRAN molecular database.[14]

10. Esplin, M.P., Sakai, H., Rothman, L.S., Vanasse, G.A., Barowy, W.M., and Huppi, R.J. (1986) Carbon Dioxide Line Positions in the 2.8 and 4.3 Micron Regions at 800 Kelvin, AFGL-TR-86-0046, ADA 173808.

11. Barowy, W.M., Esplin, M.P., Vanasse, G.A., and Huppi, R.J. (1987) Medium- and Long-Wave Infrared Absorption Spectra of Carbon Dioxide and Nitrous Oxide at 800K, AFGL-TR-87-0016, ADA 179430.

12. Esplin, M.P., and Rothman, L.S. (1983) Spectral measurements of high temperature isotopic carbon dioxide in the 4.3 μm-region, J. Mol. Spectrosc., 116:351.

13. Esplin, M.P., and Rothman, L.S. (1986) Spectral measurements of high temperature isotopic carbon dioxide in the 4.5- and 2.8-μm regions, J. Mol. Spectrosc., 100:193.

14. Rothman, L.S., Gamache, R.R., Goldman, A., Brown, L.R. Toth, R.A., Pickett, H.M., Poynter, R.L., Flaud, J.-M, Camy-Peyret, C., Barbe, A., Husson, N., Rinsland, C.P., and Smith, M.A.H. (1987) the HITRAN database: 1986 edition, Appl. Opt., 26:4058.

Table 1. Summary of Results of High Temperature Studies

Molecule	Number of Bands	Wavelength Region (μm)	Where Results Reported
$^{14}N_2{}^{16}O$	18	8	This report
$^{12}C^{16}O_2$	19	4.3	AFGL-TR-86-0046*
$^{13}C^{16}O_2$	15	4.3	AFGL-TR-86-0046*
$^{13}C^{16}O^{18}O$	5	4.4	AFGL-TR-86-0046*
$^{12}C^{18}O_2$	5	4.3	AFGL-TR-86-0046*
$^{12}C^{16}O^{18}O$	5	4.3	AFGL-TR-86-0046*
$^{12}C^{16}O^{18}O$	5	4.4	AFGL-TR-87-0016**
$^{13}C^{16}O^{17}O$	1	4.4	AFGL-TR-86-0046*
$^{12}C^{16}O_2$	11	2.7	AFGL-TR-86-0046*
$^{12}C^{16}O^{18}O$	10	2.8	AFGL-TR-86-0046*
$^{12}C^{16}O_2$	2	2.8	AFGL-TR-86-0046*

*ADA 173808

**ADA 179430

4. THE EXPERIMENTAL SETUP

The experimental apparatus consists of an infrared source, a high temperature absorption cell and the AFGL high resolution interferometer. A Nernst glower was used as the source of the infrared energy. The high temperature cell that was used has been described previously.[15] The central one-meter section of this cell can be heated to 800K and is triple passed using the Pfund configuration. The total absorption path of the cell is 3.5 meters, 3 meters of uniform high

15. Dalton, W.S., and Sakai, H. (1980) Absorption cell for the infrared spectroscopy of heated gas, Appl. Opt., 19:2413.

temperature and 1/4 meter on each end of the cell where the temperature drops to near ambient. Significant features of the AFGL High Resolution Interferometer include the use of cat's eye retro-reflectors, step and integrate instead of continuous carriage motion, and a digital demodulation and integration scheme.

The primary advantage of cat's eye retro-reflectors over flat mirrors is that cat's eyes are insensitive to tilt making it much easier to maintain alignment as the interferometer is scanned. A cat's eye retro-reflector also laterally displaces input and output beams making it possible to access both output beams. The optical signals from these two beams are complementary and so it is possible to use two detectors and operate them in a push-pull mode thus canceling out common mode errors. Using dual detectors also helps to reduce the effects of nonlinear detectors.[16] The two Cu:Ge detectors of the AFGL high resolution interferometer are mounted in the same liquid helium dewar. Using only one dewar reduces cooling costs and increases convenience. It also helps match the conditions experienced by the two detectors making the common mode rejection work better.

In our apparatus the infrared beam is chopped before entering the high temperature absorption cell. The infrared signals are then detected, demodulated, and integrated digitally. The digital data system allows for fast settling time after a step, but long integration time during data taking. It is also used to compensate for small amounts of chopper jitter and slight phase variations between the two complementary infrared channels.

Several components of the experimental apparatus have been reworked during this reporting period.[10,11] Previously, the maximum usable wavelength of the interferometer was about 7 μm, but by installing a KBr beamsplitter and Ge:Cu detectors the usable wavelength coverage has been extended to approximately 20 μm. The infrared source chamber was also totally rebuilt. In addition to these modifications, others are underway to increase the accuracy, reliability, and ease of use of the interferometer. These additions include a new stabilized reference laser, an improved KBr beamsplitter, a remotely operable filter wheel, and a new data system.

16. Guelachvili, G. (1986) Distortion free interferograms in Fourier transform spectroscopy with nonlinear detectors, Appl. Opt., 25:4644.

4.1 Reference Laser

A new stabilized reference laser, a Laboratory for Science Model 220, has been installed in the interferometer. It has a long-term frequency drift of less than 50 kHz/day. Long-term stability is particularly important for use with a step and integrate interferometer like the AFGL high resolution interferometer where each spectral scan can require up to 15 hours. If the potential stability of the laser is to be realized, the laser must be maintained in a controlled environment. In addition to controlling the physical environment for the laser, retro-reflections of the laser beam must also be controlled.

The laser head of the Laboratory for Science Model 220 laser is physically separate from the power supply and most of the other electronics. It is only the laser head that must be placed in a controlled environment. The interferometer is operated in a vacuum, but the laser must be kept at atmospheric pressure so the laser head was placed in a pressurized enclosure and cables routed to the exterior of the vacuum chamber where the rest of the electronics were located. The previous reference laser also needed to be maintained at atmospheric pressure, but due to different mechanical designs of the two lasers it was not possible to place the new laser in the old laser enclosure; thus it was necessary to design and construct a new laser enclosure. The design of this enclosure is given in Figure 1.

The long term stability of the laser is very sensitive to maintaining the laser head at a fixed temperature. To do this, we maintain the laser head packaging at an elevated temperature. This presents a problem because the pressure enclosure must provide adequate ventilation to prevent temperature buildup. The laser head can be cooled by circulating air through the enclosure if extreme caution is used to ensure that the air flow is laminar. Passing the laser beam through a turbulent airflow would introduce fluctuation in the laser beam and turbulent air around the laser head would interfere with the operation of the laser cavity length servo.

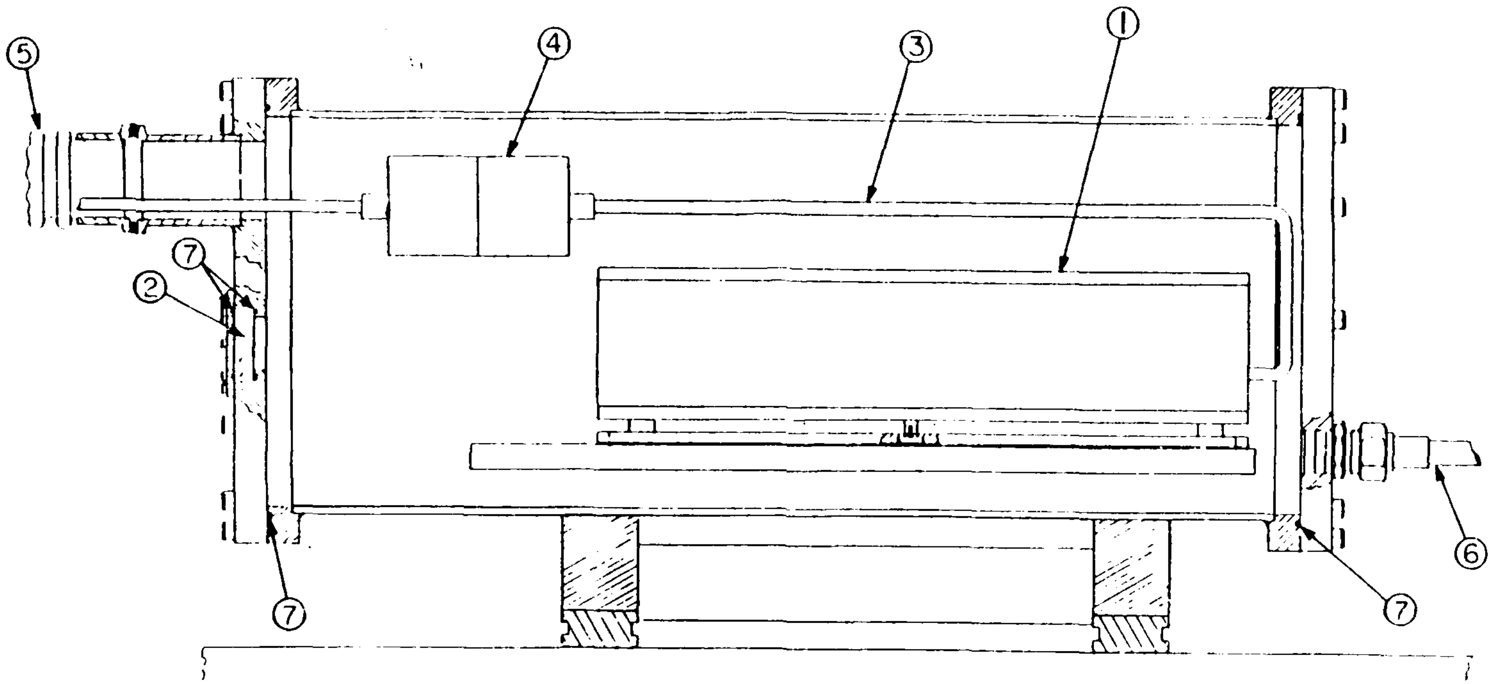

Figure 1. Reference Laser Pressure Enclosure. (1) Reference laser, (2) output window, (3) electrical cables, (4) cable connector, (5) flexible coupling to outside of vacuum chamber, (6) cooling line, and (7) O-ring seals

An additional complication arises since the reference laser uses transverse Zeeman stabilization. This method of stabilization is very susceptible to retro-reflected radiation. Careful design was needed to insure that retro-reflected energy from the interferometer did not reenter the laser. An interferometer like the AFGL High Resolution Interferometer that uses cat's eye retro-reflectors is very susceptible to backscattered radiation problems. Backscattered radiation comes primarily from the cat's eye secondary where the laser beam is brought to a focus. A small particle of dust or surface imperfection on the secondary can easily scatter considerable light back into the laser. We have found that a neutral density filter provided adequate isolation from backscattered radiation. Passing the beam through a neutral density filter reduces backscattered radiation since the light that is backscattered has to pass through the filter twice while the desired output beam only passes through the filter once. Hence, a neutral density filter with an attenuation of 10 will reduce the backscattered radiation by a factor of 100. The new laser is more powerful than the old laser, so the reduction in intensity by a factor of 10 is not a serious problem. If it proves necessary in the future, very much higher levels of isolation can be accomplished by passing the laser beam through a polarizer and a quarterwave plate.

4.2 Beamsplitter

The KBr beamsplitter used in the AFGL High Resolution Interferometer to perform the N_2O measurements had some deficiencies and so has now been replaced. It had been in storage for a number of years and had lost some of its flatness, although it performed satisfactorily in the longer wavelength regions used for the N_2O measurements. In addition, the beamsplitter coating was such that the RT product of the beamsplitter was low in the 4 μm region. The coatings on the old beamsplitter consisted of a single layer of germanium. The germanium coating was thicker on the portion of the beamsplitter used for the infrared than for the reference laser. The new beamsplitter uses different coating materials for the two regions.

The most serious problem with the old beamsplitter was that the germanium coating used for the reference laser was excessively absorbing. The absorption was high enough to make the beamsplitter appear more like a metallic than a dielectric beamsplitter. The difference between an interferometer using a metallic beamsplitter and a dielectric beamsplitter is the phase between the two beams. With a metallic beamsplitter the outputs of the two beams are in phase while with a dielectric beamsplitter they are complementary.[17] With a dielectric beamsplitter,

17. Mertz, L. (1965) Transformation in Optics, John Wiley, New York.

since the signals from the two detectors are complementary, it is possible to operate the electronics in a push-pull mode resulting in common-mode rejection. With the old KBr beamsplitter it was possible to operate the infrared detectors in a complementary manner, but not the laser reference detectors. With the new beamsplitter it will be possible to operate both the infrared and the laser reference detectors in a complementary mode.

4.3 Filter Wheel

Although a Michelson Interferometer can cover a very wide wavelength range, the photon noise produced at each spectral interval is spread through the entire spectrum. Hence, higher signal-to-noise ratios are attained if the wavelength range of the input radiation is limited with an optical filter. Since this optical filter is located inside the interferometer enclosure, it was necessary to deflate the vibration isolation pads and bring the interferometer enclosure to atmospheric pressure to change this optical filter. Since the AFGL High Resolution Interferometer is a slow scanning instrument (up to 15 hours), the long-term stability of the instrument is extremely critical. More consistent results are obtained if the interferometer is allowed to equilibrate for several days after having been opened. Hence changing the optical filter resulted in several days of lost opportunity to take data. To get around this problem a *six position filter wheel* has been installed in the interferometer vacuum enclosure that can be operated from outside of the vacuum tank. The design of this filter wheel is shown in Figure 2.

4.4 Data Aquisition System

A new data system is currently being implemented using an IBM AT compatible computer to replace the old system which was based on an outdated PDP 8/e computer. With the PDP 8/e system, only data acquisition and control of the interferometer were performed locally, and all subsequent processing of the data was performed using a Control Data mainframe computer. With the new system, much more of the processing of the data will be possible locally. The ability to perform "quick-look" checks on the data before transferring it to the mainframe will be particularly valuable. Given the rapid progress in the computer industry, in the near future it should be possible to obtain a microcomputer with sufficiently high performance to perform the entire data processing on a microcomputer.

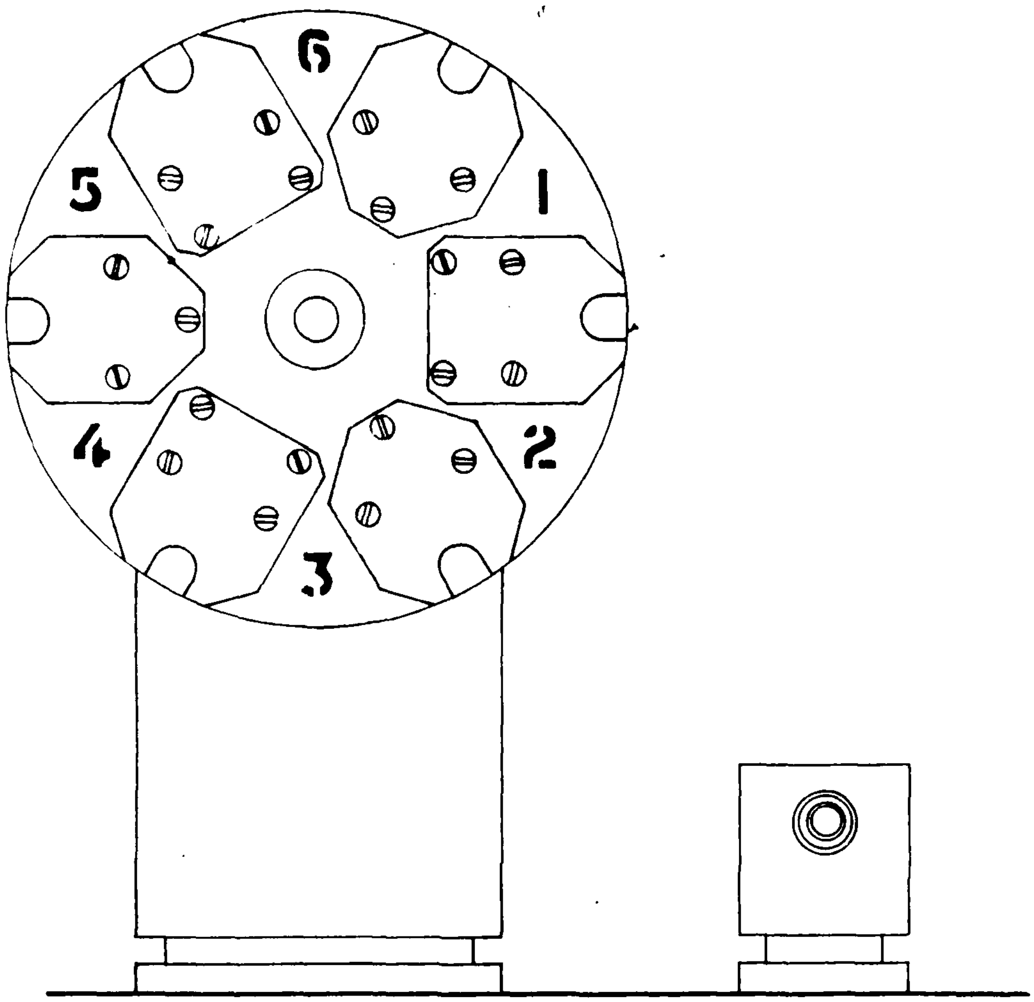

Figure 2. Design of Optical Filter Wheel

The main advantages of using an IBM PC for an interferometer controller are low costs and the flexibility made possible by the large number of available hardware and software options. However in many ways, the PDP 8/e was better suited for use as a programmable controller than an IBM PC computer. The PDP 8/e is a synchronous machine with a very simple non-intrusive operating system. With the PDP 8/e, the computer is never servicing an interrupt when a time critical operation is in progress. Also since the PDP 8/e is synchronous, the time required to perform each instruction is always the same, making it possible to perform timing by using the speed of the computer instructions themselves. With an IBM PC on the other hand, since the time required to perform a given operation is not constant, the computer cannot be counted on to perform time critical operations without the aid of additional hardware. (In principle it is possible to turn off

the interrupt on the IBM PC, but since the operating system and the hardware of the computer are very closely integrated this is not a very satisfactory solution.) These disadvantages are largely overcome by the manufacturers of the data acquisition systems supplying complete data acquisition subsystems instead of just simple analog to digital converters. For example, the MetraByte Dash-16 board used in the new data acquisition system includes, in addition to the analog to digital converters, timing and logic circuits as well as the necessary software drives to use them.

The new data acquisition and control software is written in FORTRAN 77, in contrast to the old PDP 8/e system which was written in absolute loaded assembly language. Assembly language programs in general tend to use the hardware more efficiently, but they are also much more dependent on the details of the hardware. The reason we have been using a PDP 8/e long after it has become obsolete is because of the high manpower cost required to rewrite the data acquisition and control program to make use of new hardware. It should be relatively easy to modify the new system to keep up with advances in hardware. The ease of programming in a higher level language and the availability of commercially available graphics and mathematical software, also makes it practical to write software which is considerably easier to use and much more capable.

5. N_2O MEASUREMENTS

Spectra were measured at several different temperatures and pressures to facilitate the line assignment process and to maximize the number of spectral lines measured under optimum conditions. After checking each of these spectra for consistency, they were co-added to obtain one spectrum for each temperature and pressure. The experimental conditions under which spectra were measured and the number of experimental spectra taken are listed in Table 2. Measurements of the spectrum of the empty absorption cell were interspersed between the N_2O spectra. These empty cell measurements were used to determine the 100 percent transmission levels. The maximum retardation of the interferometer for all spectra was 83 cm, resulting in a resolution of 0.006 cm^{-1}.

Table 2. Experimental Conditions for N_2O, $\delta\sigma = 0.006\ cm^{-1}$

Number of Spectra	Temperature	Pressure
2	300K	1.0 Torr
2	473K	2.3 Torr
2	473K	9.0 Torr
2	800K	4.0 Torr
2	800K	15. Torr

Additional spectra not included in Table 2 were the first obtained at 800K; however, few absorption features were observed. As these were spectra of the first samples run at 800K, it appears plausible that the high temperature N_2O was reacting with the walls of the cell. Residue from the initial reactions prevented further loss of N_2O, enabling successful recording of the interferograms that followed.

The spectra were calibrated using an internal calibration technique. Toth has published a paper[18] in which he reports the analysis of room temperature N_2O spectra that were taken using the high resolution Fourier spectrometer located in the McMath solar telescope facility at the Kitt Peak National Observatory. Since his data were taken at room temperature the lines that he observed do not extend to as high rotational states (J values) as in this work. The calibration was performed by adjusting the wavelength scale of the observed spectra until, on the average, the observed line positions for the low J lines matched the values obtained by Toth.

During the calibration process it was noted that there were some systematic shifts between the positions of strong and weak lines in spectra taken at high temperatures. This effect is presently being investigated, but is probably due to non-uniform illumination of the detectors causing a slightly asymmetric instrumental line shape. Evidence to support this conclusion is that the quality of the infrared beam has been observed to be much poorer at the higher temperatures than at room temperature. The primary cause of this beam degradation was probably due to the

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18. Toth, R.A. (1986) Frequencies of N_2O in the 1100 to 1440 cm^{-1} region, J. Opt. Soc. Am., 3:1263.

distortion of the mirrors in the absorption cell as the cell was heated. Even for the low J lines of the ν_1 fundamental where this effect was most noticeable, the error was only 0.0007 cm^{-1}.

5.1 Treatment of the Data

The line assignments for each band were performed by starting at low J, where Toth's molecular constants were valid, and working to high J. After the line assignments had been made, data from all the different temperatures and pressures were combined into a single data set and a final weighted least-squares-fit was performed to obtain new effective molecular constants. Although over 4100 lines were identified in the experimental spectrum, only 3454 were used in the least-squares-fit, due to line merging problems. Many of the remaining lines were slightly affected by the presence of close-by spectral lines. These slightly merged lines were included in the least-squares fit, but with reduced weighting. Each band was fit independently without making any attempt to combine the information from the various bands into a single global self-consistent set of energy levels for the N_2O molecule.

In order that this weighted least-squares-fitting procedure could be used, it was necessary that an estimate of the uncertainty of each experimental line be made. The weight assigned each spectral line was the reciprocal of the expected uncertainty squared. The factors that went into calculating the expected uncertainty of each line were: the random experimental noise in the spectrum, line asymmetry, abnormal width of spectral lines, and inconsistencies of line positions compared to other lines in the same band. The total uncertainty for each line was defined as the square root of the sum of squares of the individual uncertainties. Further details of the methods used to determine the weights for the least-squares-fits were described in a previous report.[10]

The most noticeable effect of using a weight for each spectral line was to substantially reduce the uncertainty in the spectroscopic constants as predicted by the least-squares-fitting program. However, the spectral line positions calculated using the resulting constants were found to be quite insensitive to the values of the weights chosen. This indicates that the effects of line merging on the position of spectral lines were essentially random for the high temperature spectra considered in this study.

5.2 Data Analysis Software

Even though the data analysis software had been used in analyzing asymmetric species of CO_2 that have similar structure to N_2O it was still necessary to modify the software to take into account that N_2O is less "harmonic oscillator like" than CO_2. The energy expansion in terms of G, B, D, and H doesn't work as well, so it was necessary to include an additional term, L. This is partly due to the fact that Coriolis perturbation plays a larger role with N_2O than it does with CO_2. Adding L's to the fitting program made it necessary to change the format of the molecular constant data files and the formats of all the subsequent programs that use these molecular constant files.

In working with the least-squares-fitting program it became apparent that because of numerical instabilities adding L's was more involved than just adding an additional term to the fitting function. The relative size of the constants that were being fitted ranged from the order of 10^3 for G to 10^{-18} for L. This large variation in the size of the fitted parameters created problems with numerical roundoff in the inversion of the matrix that was used to obtain least-squares-fit to molecular constants. It was found that the numerical stability of the molecular constants was considerably improved by scaling the constants and including their order of magnitude into the fitting equation. Therefore in the numerical matrix inversion and in the determination of the constants all the constants were of nearly the same magnitude. If it would have been necessary, additional least-squares techniques could have been used to reduce the numerical instabilities further.

In addition to changing the software to include L's, several other changes were made to make the software easier to modify in the future. One of these changes was to convert the programs from Control Data Corporation FORTRAN IV to generic FORTRAN 77. Converting to FORTRAN 77 also eliminated the inconvenience of being tied to a single computer.

There are many advantages in using more than one computer to perform data analysis. The computer work was performed partly on an IBM-PC compatible and partly with a Control Data Corporation (CDC) mainframe computer. Due to the more convenient operating environment and better editors, it was found to be more productive to perform program editing as well as much of the program development on an IBM-PC compatible. However, most of the actual data analysis was performed using the CDC mainframe due to faster execution speeds and larger disk storage size. An additional advantage of using two computers, with different word sizes and which handle floating point calculation differently, is the ability to quickly detect numerical roundoff in the algorithms that are being used. The same calculation can be run on both computers and the results compared, thus checking for numerical roundoff.

5.3 Results and Discussion

The 18 rotation-vibration bands of N_2O for which molecular constants were obtained are indicated on the energy level diagram of Figure 3. The range of P and R lines used in the least-squares fits, the total number of lines, and the rms error for each band is given in Table 3. The effective molecular constants which were obtained are given in Table 4. The line position, observed minus calculated, and expected uncertainty of each line used in the least-squares-fit are given in the appendix. These constants are effective molecular constants and so should not be expected to accurately represent the internal structure of the N_2O molecule. The purpose of these effective constants is to provide a means of reproducing, within the experimental accuracy, the position of spectral lines over the range of J values covered by the measurements (see Table 3). There are a great many interactions between different vibrational states for the N_2O molecule. The effects of these interactions are accounted for by allowing the different effective molecular constants to float freely in the least-squares-fit of each band. Molecular constants obtained in this manner are not self-consistent. For example, the molecular constants obtained for the vibrational state 1110 from the 1110 ← 0110 band are not consistent with those obtained from the 1310 ← 1110 band.

An interesting observation that becomes apparent from studying both CO_2 and N_2O is that the interactions between levels not involved in Fermi resonances are much stronger for N_2O than for CO_2. These interactions result in N_2O being less "harmonic oscillator like" than CO_2. The effects of these interactions can be seen in Table 4 in the magnitude of the inconsistencies of effective molecular constants determined from different bands and from the extremely large values for L's which are obtained for some bands.

Each band was fit twice, once using L's and once without. The spectroscopic constants (L′ for the upper state and L″ for the lower state) were included in the final least-squares fit only when their inclusion markedly improved the quality of the fit (a reduction in the rms error of more than 20 percent) and the uncertainties in L were smaller than the value of L for both the upper and the lower states. Occasionally, an exception was made for bands where l-type doubling was present (bands where $l > 0$). If the e levels indicated the need of an L and the f levels did not, for consistency L's were used for both sets of levels.

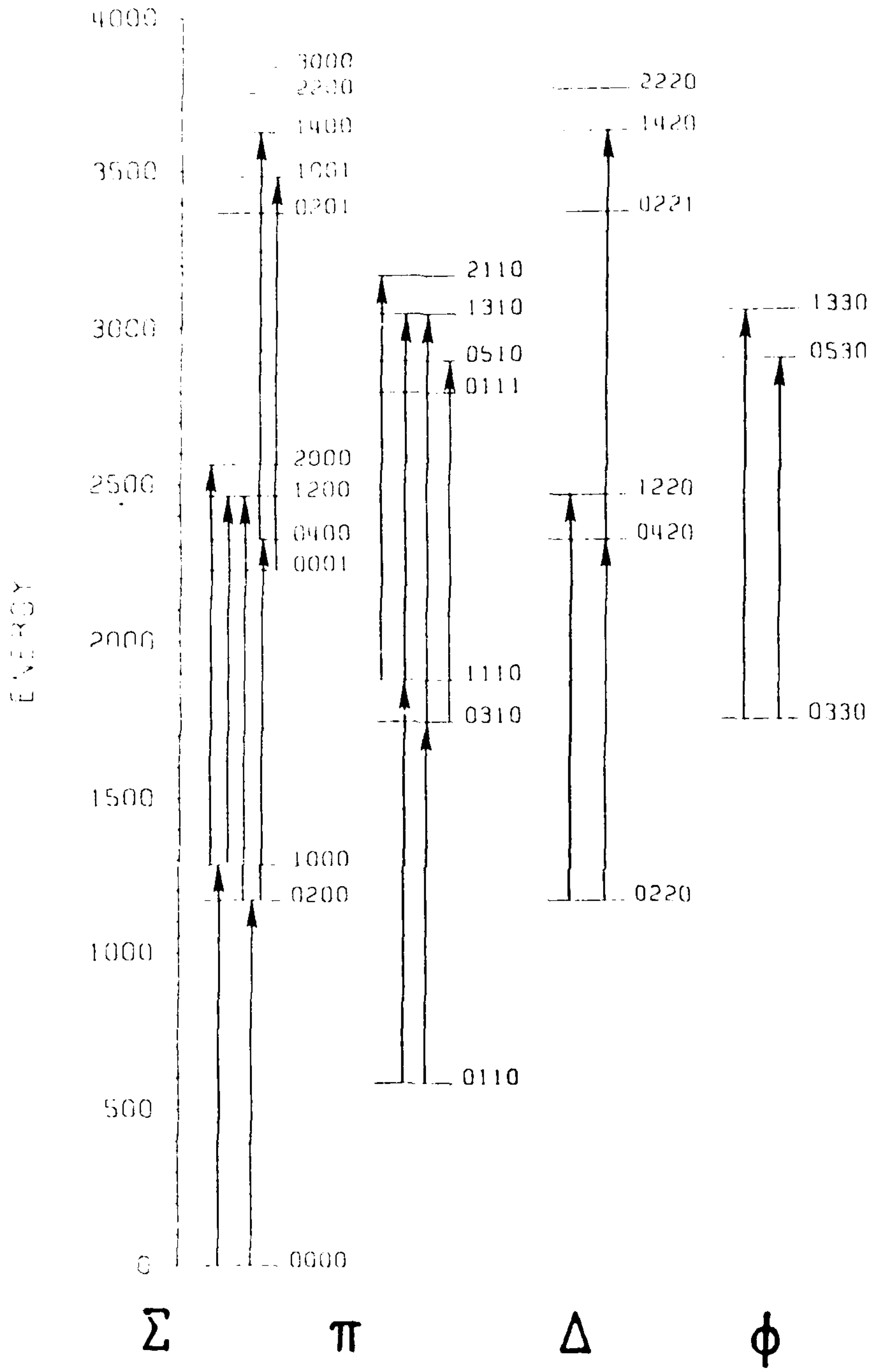

Figure 3. N_2O Energy Level Diagram Showing Observed Rotation-Vibration Bands

Table 3. Observed N_2O Bands

Transition		Band Center (cm^{-1})	Range of Measurement	Number of Lines	RMS Error x$10^{[illegible]}$ cm^{-1}
1000	0000	1284.9027	P(105)-R(104)	205	3
1110e	0110e	1291.4978	P(90)-R(100)	181	3
1110f	0110f	1291.4978	P(94)-R(95)	176	3
0200	0000	1168.1319	P(83)-R(82)	156	3
0310e	0110e	1160.2973	P(73)-R(73)	137	4
0310f	0110f	1160.2973	P(75)-R(66)	132	3
1200	0200	1293.8641	P(89)-R(88)	162	3
1200	1000	1177.0927	P(64)-R(62)	104	5
1220e	0220e	1297.0542	P(83)-R(83)	155	7
1220f	0220f	1297.0542	P(89)-R(86)	147	4
2000	1000	1278.4359	P(93)-R(90)	157	3
0400	0200	1154.4403	P(63)-R(68)	119	5
0420e	0220e	1153.3767	P(59)-R(59)	101	9
0420f	0220f	1153.3767	P(65)-R(64)	102	7
1310e	0310e	1297.1481	P(83)-R(84)	125	5
1310f	0310f	1297.1481	P(86)-R(80)	124	5
1310e	1110e	1165.9488	P(58)-R(54)	60	9
1310f	1110f	1165.9488	P(60)-R(55)	61	8
1330e	0330e	1301.8082	P(86)-R(81)	136	8
1330f	0330f	1301.8082	P(81)-R(81)	142	9
0530e	0330e	1147.1321	P(53)-R(59)	74	13
0530f	0330f	1147.1321	P(50)-R(60)	74	14
2110e	1110e	1285.5881	P(86)-R(84)	130	5
2110f	1110f	1285.5881	P(84)-R(77)	124	4
1001	0001	1257.0628	P(77)-R(68)	100	6
1400	0400	1298.3692	P(57)-R(64)	85	7
1420e	0420e	1300.4682	P(59)-R(65)	87	9
1420f	0420f	1300.4682	P(75)-R(64)	98	9

Table 4. Effective Molecular Constants (cm^{-1})

Transition		G' - G"	B'	D'x10^7	H'x10^13	L'x10^18	B"	D"x10^7	H"x10^13	L"x10^18
1000	0000	1284.9027	.41725521	1.72394	.6975	7.65	.41901092	1.75890	-.5596	2.21
1110e	0110e	1291.4978	.41746590	1.75252	1.4499		.41917895	1.78609	.0300	
1110f	0110f	1291.4978	.41837171	1.71922	2.4116		.41996848	1.79178	-.1457	
0200	0000	1168.1319	.41992266	2.49036	28.5104	10.11	.41901211	1.75136	-4.5817	51.65
0310e	0110e	1160.2973	.41958062	2.08957	8.4733		.41917508	1.76882	-1.7303	
0310f	0110f	1160.2973	.42108035	2.17418	-4.1519		.41997131	1.78858	-2.0909	
1200	0200	1293.8641	.41815799	2.47089	33.9835	-78.03	.41993087	2.53427	39.0163	-84.51
1200	1000	1177.0927	.41814698	2.41589	21.4196		.41725307	1.70617	-3.7088	
1220e	0220e	1297.0542	.41852958	1.20564	-26.3114		.42012475	1.19706	-29.6815	
1220f	0220f	1297.0542	.41852958	1.74873	1.5077		.42012475	1.81238	-.2943	
2000	1000	1278.4359	.41560211	1.60998	-.4333	54.65	.41725167	1.70032	-4.0245	37.87
0400	0200	1154.4403	.42063687	4.21422	246.7177	-1227.71	.41993353	2.65555	88.4033	-601.82
0420e	0220e	1153.3767	.42077256	.17872	-148.6218		.42012696	1.17787	-37.1404	
0420f	0220f	1153.3767	.42077256	2.15646	3.1991		.42012696	1.81663	-.8965	
1310e	0310e	1297.1481	.41775533	2.08241	8.4884		.41958100	2.10173	9.3416	
1310f	0310f	1297.1481	.41937526	2.15487	2.6078		.42107864	2.19213	.8100	
1310e	1110e	1165.9488	.41775211	1.99684	-5.2920		.41745936	1.65249	-16.6968	
1310f	1110f	1165.9488	.41937305	2.16162	1.9434		.41837419	1.76630	8.9529	
1330e	0330e	1301.8082	.41911053	1.59673	-7.1452	-259.63	.42066992	1.63249	-9.4152	-239.40
1330f	0330f	1301.8082	.41911053	1.59673	7.1403	155.39	.42066992	1.63249	6.6500	157.41
0530e	0330e	1147.1321	.42123301	1.62107	-26.0673		.42067693	1.69896	8.6457	
0530f	0330f	1147.1321	.42123301	1.62107	22.8387		.42067693	1.69896	1.5053	
2110e	1110e	1285.5881	.41584427	1.68067	3.9219		.41746302	1.74802	1.2033	
2110f	1110f	1285.5881	.41691891	1.58289	6.2603		.41837292	1.71717	1.9102	
1001	0001	1257.0628	.41377588	1.64108	-9.8693		.41554941	1.67389	-11.7388	
1400	0400	1298.3692	.41879033	3.87543	136.8809		.42062538	4.04056	163.4596	
1420e	0420e	1300.4682	.41903401	.71688	92.6146	-2982.78	.42077124	.55534	63.5614	-2987.55
1420f	0420f	1300.4682	.41903401	1.84591	-124.6549	1599.29	.42077124	1.89174	-116.4074	1438.90

One of the most common ways to deal with small interactions between rotation-vibration states is through the use of contact transformations. Assuming that this technique is valid, the two sets of spectroscopic constants that occur for bands where l -type doubling occurs are not independent.[19] For these bands, several of the spectroscopic constants for the e and the f sets of levels should be constrained to be equal. This interdependence between sets of rotational constants is a function of l. When $l = 1$, the vibrational term values G_e and G_f should be constrained to be equal. When $l = 2$, in addition to having G_e equal to G_f, the rotational constants B_e and B_f should be equal. When $l = 3$, then $D_e = D_f$, and so on. These constraints seemed to work very well for the CO_2 bands considered in this study, but for N_2O they seemed to be causing some problems with the fits. One of the things that will be investigated as part of future efforts is whether these constraints should be dropped for N_2O.

The residual to the least-squares-fits are plotted in Figures 4-8 for several rotation-vibration bands. The N_2O line positions calculated using the molecular constants reported by other researchers are also indicated on these same plots. For low J lines, the N_2O positions of both Guelachvili[20] and Toth[18] are within the experimental error of the results presented in this report, but at higher J the measurements start to diverge. This result is not surprising since both Guelachvili and Toth used room temperature absorption cells. Of the two measurements Toth's is the most recent and covers a larger number of rotation-vibration bands. The line positions reported by Toth are also in better agreement with the values reported in this study than are Guelachvili's line positions. Although Toth's low J values are very accurate, they cannot be used to extrapolate the position of the high J lines observed in this study. For example if Toth's constants were used to predict the position of the high J lines, the error would sometimes be as large as 0.05 cm^{-1} (see Figure 8).

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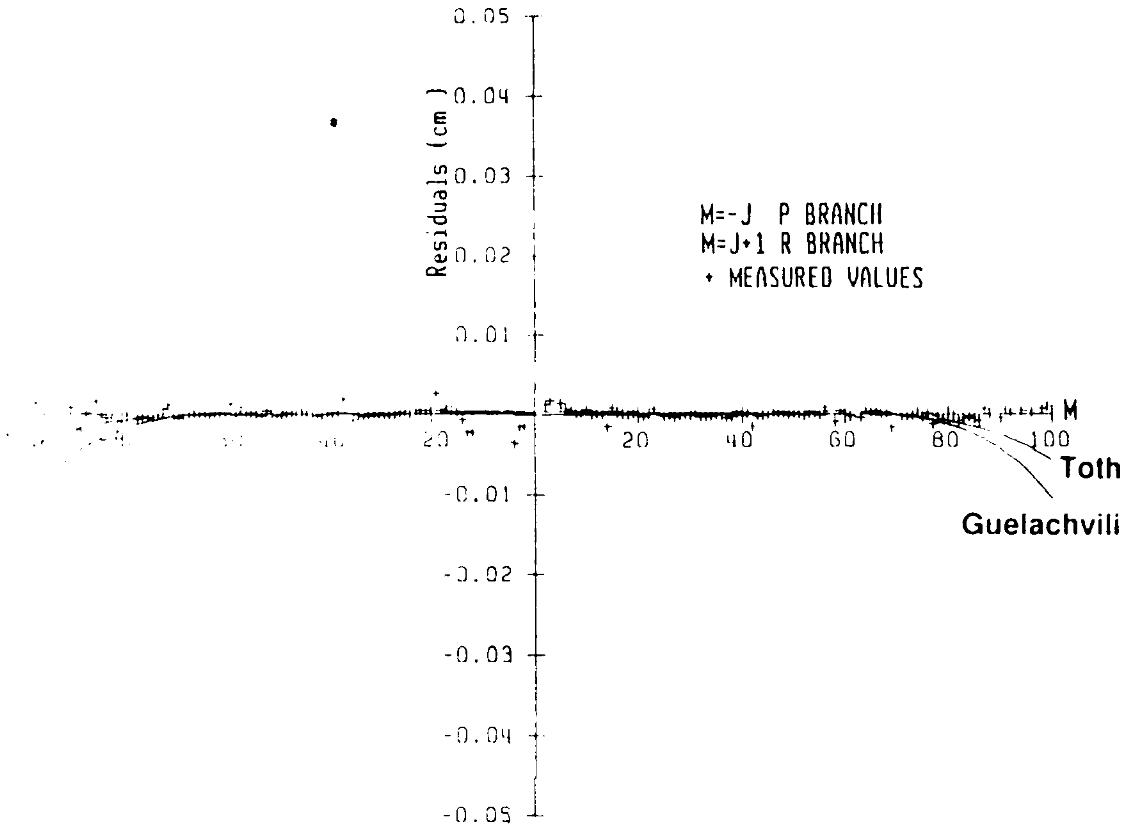

Figure 4. Comparison of Measured Line Positions With Those Computed Using Toth's and Guelachvili's Constants for the 1110e ← 0110e Band

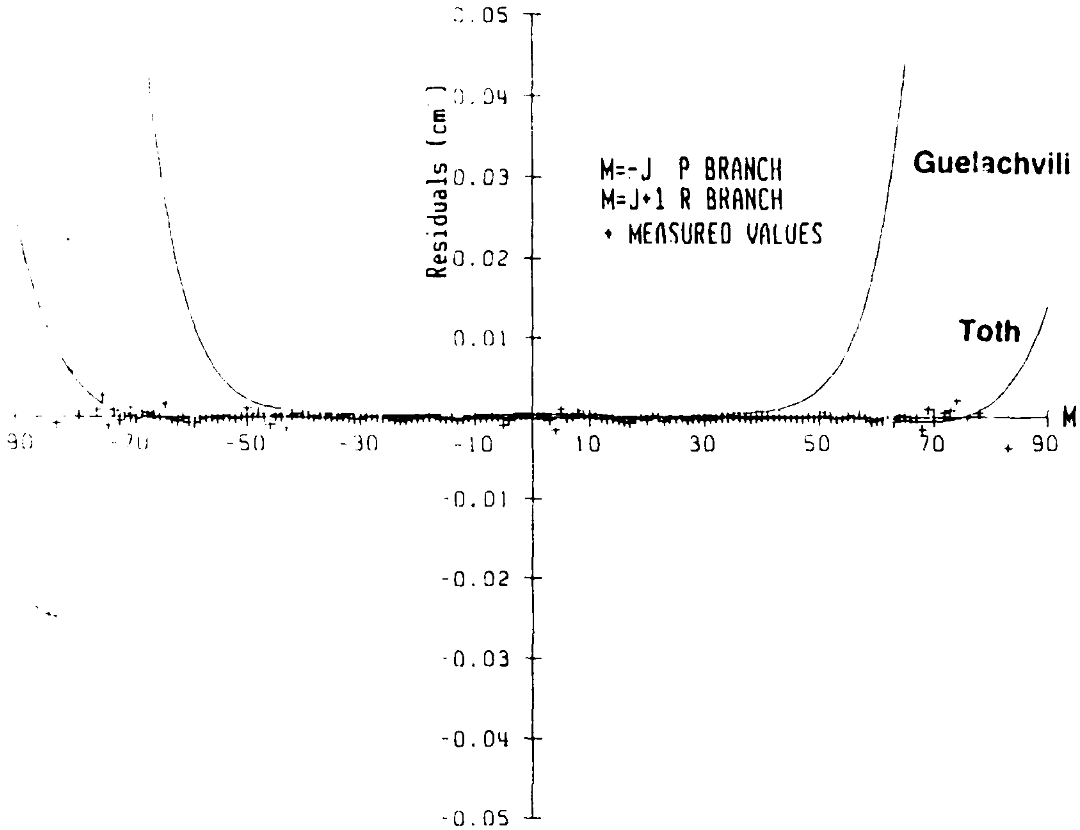

Figure 5. Comparison for the 0200 ← 0000 Band

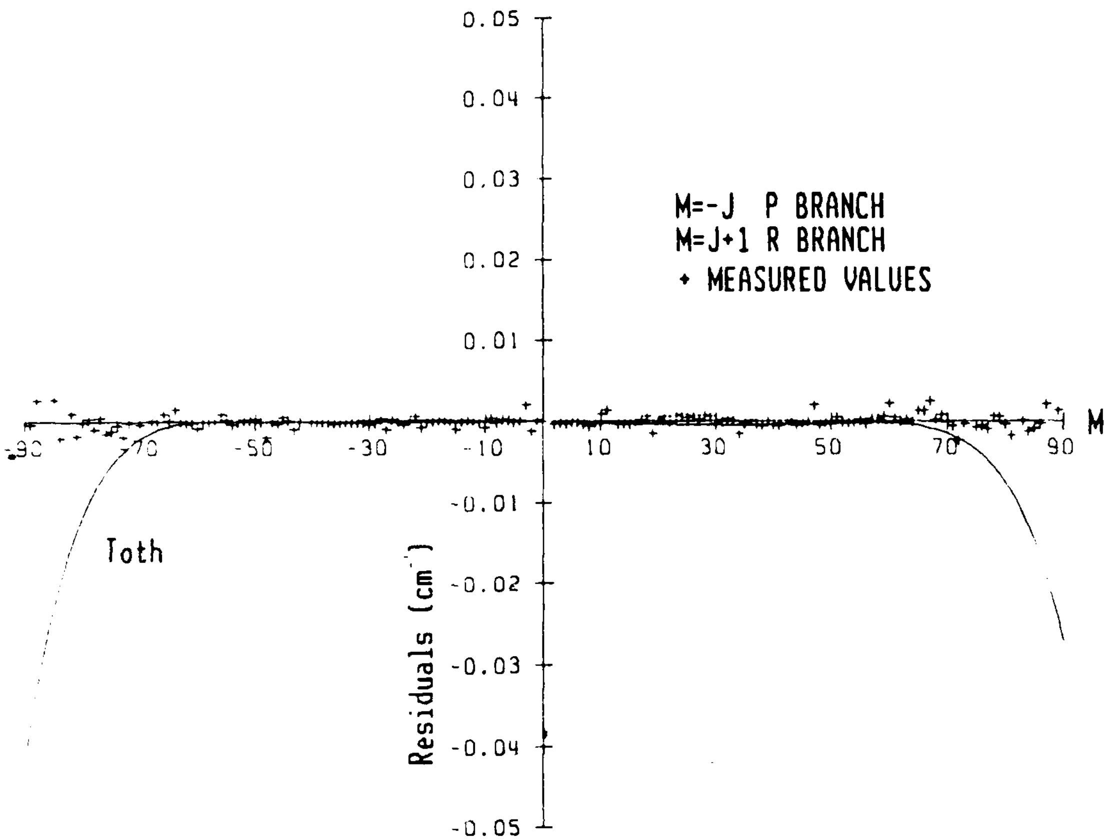

Figure 6. Comparison for the 1200 ← 0200 Band

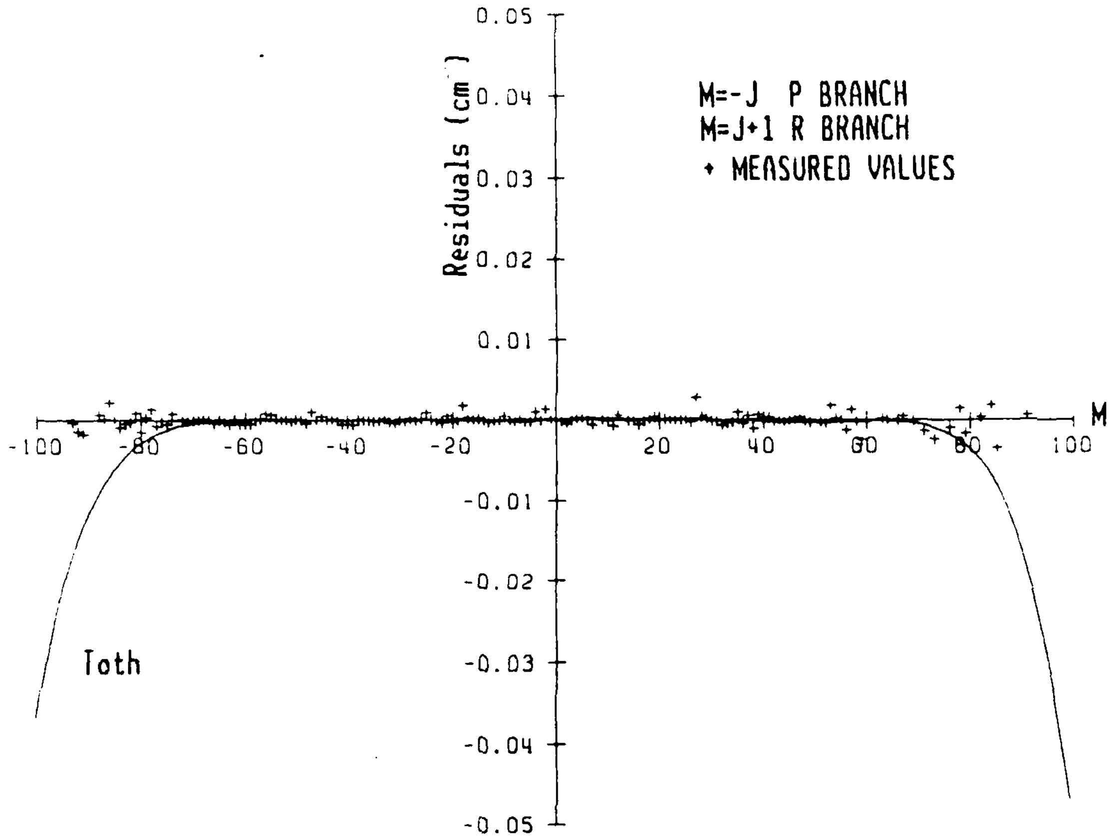

Figure 7. Comparison for the 2000 ← 1000 Band

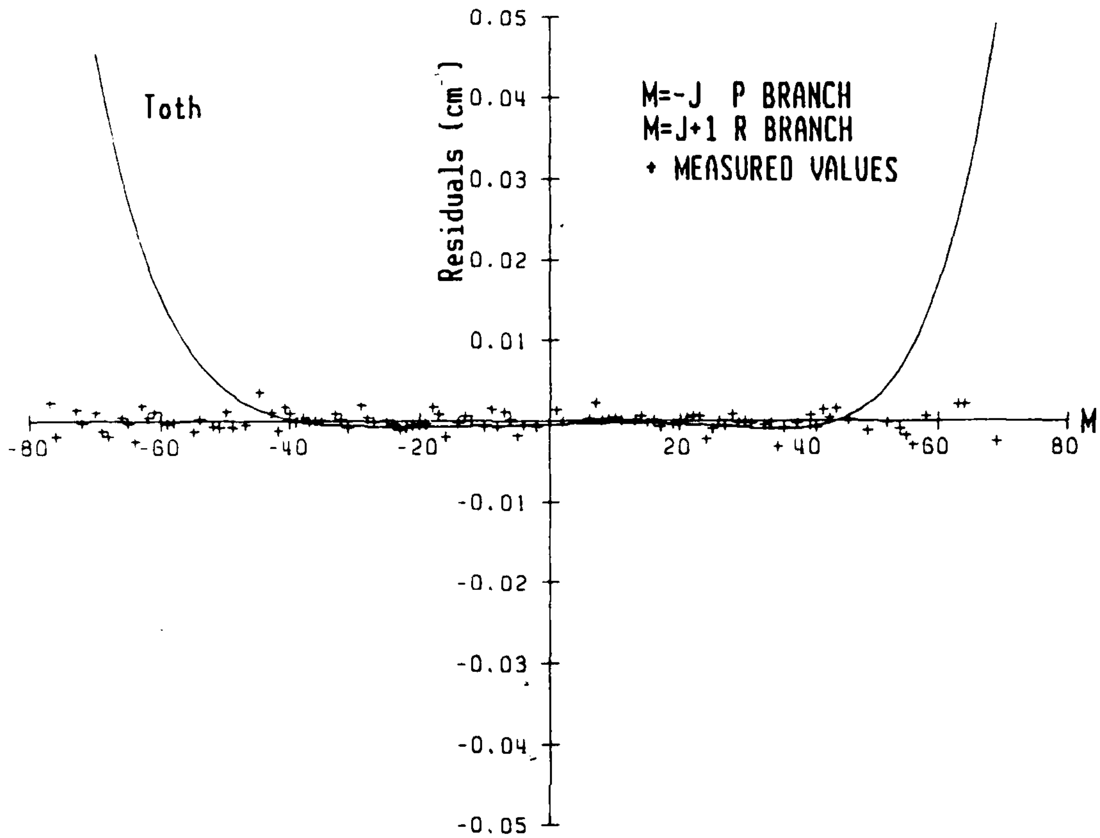

Figure 8. Comparison for the 1001 ← 0001 Band

6. CONCLUSION

During the period covered by this report an extensive study has been made on CO_2 and N_2O using the AFGL High Resolution Interferometer in conjunction with a high temperature absorption cell. This study includes the identification of over 11,000 CO_2 lines belonging to 78 different rotation-vibration bands and over 4100 N_2O lines belonging to 18 bands. Many of the high J lines for these bands have not been observed previously. A weighted least-squares-fit technique was then used to obtain effective molecular constants for each of these bands. These effective molecular constants predict the position of spectral lines originating from excited rotational states with an accuracy considerably greater than those previously available. The CO_2 data have already been incorporated into the 1986 edition of the AFGL HITRAN molecular database.[14] The N_2O data as well as the CO_2 data will be incorporated into an AFGL high temperature database that is presently being compiled.

In addition to providing data for the AFGL databases this extensive data makes it possible to come to several other interesting conclusions. Molecular constants obtained using room temperature CO_2 and N_2O are not adequate for predicting the position of spectral lines observed at high temperatures even when the room temperature measurements are extremely accurate. The interaction between levels not involved in Fermi resonances are much stronger for N_2O than for CO_2. These interactions make N_2O less "harmonic oscillator like" than CO_2.

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Appendix A

N_2O Line Position Listing

	1000 - 0000 446						2000 - 1000 446					
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
0				1285.7378	6	4				1279.2670	-1	2	0
1	1284.0652	5	4	1286.5689	7	4	1277.6016	2	3	1280.0946	-4	2	1
2	1283.2249	17	11	1287.3960	3	3	1276.7650	14	13	1280.9196	0	3	2
3	1282.3779	-2	2	1288.2197	1	2	1275.9225	0	3	1281.7411	2	3	3
4	1281.5296	0	3	1289.0408	7	3	1275.0792	11	12	1282.5591	2	3	4
5	1280.6776	0	3	1289.8570	0	3	1274.2304	-1	2	1283.3735	0	2	5
6	1279.8219	-2	3	1290.6701	-2	3	1273.3794	-2	2	1284.1842	-7	5	6
7	1278.9630	-1	3	1291.4808	7	9	1272.5256	2	3				7
8	1278.1005	-1	3	1292.2861	-3	4	1271.6678	-1	2	1285.7977	1	2	8
9	1277.2343	-3	3	1293.0892	1	3	1270.8072	0	2	1286.5988	-1	2	9
10	1276.3652	0	3	1293.8880	-3	4	1269.9438	6	4	1287.3962	-8	4	10
11	1275.4917	-6	5	1294.6842	3	4	1269.0760	1	2	1288.1923	6	4	11
12	1274.6159	-1	4	1295.4764	4	4	1268.2056	1	3				12
13	1273.7360	-2	4	1296.2642	-3	5	1267.3316	-2	2	1289.7711	0	2	13
14	1272.8526	-3	3	1297.0487	-8	8	1266.4548	0	2	1290.5558	0	3	14
15	1271.9658	-4	5	1297.8309	0	4	1265.5749	2	2	1291.3367	-5	5	15
16	1271.0760	-1	4	1298.6084	-3	6	1264.6914	1	2	1292.1152	0	2	16
17	1270.1824	-1	5	1299.3831	1	3	1263.8050	3	4	1292.8901	2	2	17
18	1269.2851	-4	5	1300.1527	-9	7				1293.6618	5	3	18
19	1268.3846	-5	5	1300.9211	4	5	1262.0219	0	2	1294.4293	0	2	19
20	1267.4811	-1	4	1301.6838	-5	6	1261.1256	-2	3	1295.1942	2	2	20
21	1266.5737	-3	4	1302.4444	2	4	1260.2269	4	4	1295.9556	2	3	21
22	1265.6632	-1	4	1303.2005	-1	5	1259.3236	-4	3	1296.7135	0	2	22
23	1264.7487	-6	5	1303.9535	1	4	1258.4182	-1	2	1297.4682	0	3	23
24	1263.8319	1	4	1304.7025	-1	4	1257.5095	0	2	1298.2196	0	2	24
25	1262.9112	2	4	1305.4483	1	3	1256.5985	9	5	1298.9674	-2	3	25
26	1261.9865	-3	7	1306.1902	0	3	1255.6826	1	2	1299.7152	29	24	26
27	1261.0598	6	5	1306.9285	-1	3	1254.7642	-1	2	1300.4542	4	3	27
28	1260.1287	4	3	1307.6638	4	3	1253.8433	3	2	1301.1921	3	2	28
29	1259.1944	4	3	1308.3949	2	4	1252.9185	-2	2	1301.9265	-1	2	29
30	1258.2565	2	3	1309.1228	5	3	1251.9913	1	2	1302.6580	-1	2	30

31	1257.3151	-2	4	1309.8458	-6	4	1251.0603	-4	3	1303.3856	-6	3	31
32	1256.3709	-1	4	1310.5675	7	5	1250.1268	-3	2	1304.1107	-4	2	32
33	1255.4230	-3	3	1311.2837	0	3	1249.1907	3	3	1304.8324	-3	3	33
34	1254.4722	-1	4	1311.9967	-2	2	1248.2507	0	2	1305.5518	9	5	34
35	1253.5181	1	2	1312.7064	-2	2	1247.3079	-1	3	1306.2654	-5	4	35
36	1252.5608	4	3	1313.4127	1	3	1246.3623	0	2	1306.9781	5	5	36
37	1251.6012	17	9	1314.1152	1	2	1245.4136	0	2	1307.6849	-11	7	37
38	1250.6349	-4	2	1314.8140	1	4	1244.4620	1	2	1308.3918	6	17	38
39	1249.6664	-14	9	1315.5090	-2	3	1243.5067	-6	4	1309.0933	2	4	39
40	1248.6972	2	3	1316.2006	-2	2	1242.5495	-1	3	1309.7920	3	2	40
41	1247.7228	-2	3	1316.8887	-1	2	1241.5885	-6	9	1310.4869	-2	2	41
42	1246.7457	0	2	1317.5730	-3	2	1240.6255	-1	2	1311.1793	1	3	42
43	1245.7652	1	3	1318.2542	1	2	1239.6594	1	2	1311.8680	-2	2	43
44	1244.7813	-1	2	1318.9312	-2	2	1238.6900	0	2	1312.5540	1	3	44
45	1243.7945	1	3	1319.6049	-2	2	1237.7184	5	4	1313.2366	2	2	45
46	1242.8041	0	2	1320.2759	8	5	1236.7430	1	2	1313.9161	4	4	46
47	1241.8107	0	2	1320.9412	-4	3	1235.7662	10	6	1314.5917	-1	2	47
48	1240.8140	0	3	1321.6045	0	3	1234.7842	-3	3	1315.2644	-4	3	48
49	1239.8142	0	3	1322.2638	1	3	1233.8013	2	3				49
50	1238.8112	0	3	1322.9196	1	3	1232.8151	1	2	1316.6011	-1	3	50
51	1237.8052	2	3	1323.5721	5	4	1231.8259	-2	2	1317.2644	-4	3	51
52	1236.7957	0	3	1324.2204	3	3	1230.8345	1	2				52
53	1235.7833	1	3	1324.8653	2	3	1229.8401	0	2	1318.5828	3	2	53
54	1234.7678	3	3	1325.5066	1	3	1228.8432	2	2	1319.2368	0	2	54
55	1233.7488	0	2	1326.1442	-1	3	1227.8440	6	4				55
56	1232.7269	0	2	1326.7787	2	3	1226.8419	9	4	1320.5374	13	6	56
57	1231.7020	0	2	1327.4092	0	3	1225.8362	1	3	1321.1811	-1	3	57
58	1230.6740	1	3	1328.0365	2	4	1224.8286	0	3	1321.8208	-25	14	58
59	1229.6428	0	2	1328.6602	3	2	1223.8181	-5	3				59
60	1228.6086	0	2	1329.2800	1	2	1222.8058	-2	3				60
61	1227.5716	2	2	1329.8966	2	3	1221.7905	-4	3				61
62	1226.5309	-2	3	1330.5093	-1	2	1220.7735	1	3	1324.3623	1	3	62
63	1225.4876	-2	2	1331.1186	-2	2	1219.7530	-4	4	1324.9896	0	5	63
64	1224.4417	2	2	1331.7251	4	3	1218.7309	-2	5				64
65	1223.3921	-1	2	1332.3270	-1	2	1217.7065	1	4	1326.2359	-1	4	65
66	1222.3401	1	3	1332.9256	-4	2	1216.6789	-4	4	1326.8554	4	10	66
67	1221.2848	0	2				1215.6500	1	4				67

68	1220.2266	0	2	1334.1133	0	3	1214.6185	2	5	1328.0846	-1	5	68
69	1219.1649	-6	5	1334.7034	17	9	1213.5846	1	4				69
70	1218.1016	1	2	1335.2867	0	2	1212.5485	0	4	1329.3022	-14	9	70
71	1217.0348	2	2	1335.8683	1	2	1211.5103	-1	5				71
72	1215.9648	-1	3	1336.4462	0	2	1210.4702	1	5	1330.5097	-23	20	72
73	1214.8921	-2	2	1337.0207	-1	2							73
74	1213.8168	0	2	1337.5924	4	2	1208.3844	8	11				74
75	1212.7362	-24	22	1338.1597	-1	2	1207.3368	-5	6	1332.3048	-9	10	75
76	1211.6575	0	2	1338.7243	1	2	1206.2891	-1	6				76
77	1210.5737	0	3	1339.2851	-1	2	1205.2385	-6	8	1333.4909	15	8	77
78	1209.4869	-3	3	1339.8422	-6	10	1204.1887	14	11	1334.0762	-16	12	78
79	1208.3975	-4	3	1340.3970	-1	3	1203.1341	3	4				79
80	1207.3060	1	4	1340.9478	-2	3	1202.0770	-15	14				80
81	1206.2114	2	4	1341.4962	6	4	1201.0224	8	7	1335.8299	3	9	81
82	1205.1140	1	4	1342.0397	-3	3	1199.9629	-2	9				82
83	1204.0140	1	3	1342.5806	-4	5	1198.9026	-5	13	1336.9888	19	11	83
84				1343.1183	-5	5	1197.8407	-10	11	1337.5592	-35	14	84
85	1201.8059	-3	4	1343.6535	2	4	1196.7789	1	8				85
86	1200.6980	-5	7	1344.1847	1	3	1195.7169	22	19				86
87	1199.5888	5	5	1344.7129	2	5	1194.6494	1	4				87
88				1345.2375	-1	5	1193.5835	7	17				88
89	1197.3599	-5	6	1345.7596	2	4							89
90	1196.2427	-1	5	1346.2771	-9	10				1340.9806	6	16	90
91	1195.1230	2	5	1346.7933	-3	5	1190.3752	-17	16				91
92	1194.0009	4	5	1347.3061	1	5							92
93	1192.8760	2	5	1347.8147	-8	6	1188.2350	-3	13				93
94	1191.7480	-8	7	1348.3227	8	6							94
95	1190.6204	8	6	1348.8265	12	6							95
96	1189.4870	-12	20	1349.3251	-7	21							96
97	1188.3555	10	6	1349.8237	4	9							97
98	1187.2203	15	16	1350.3142	-38	10							98
99	1186.0832	23	21	1350.8080	-18	10							99
100	1184.9400	-10	13	1351.2998	10	11							100
101				1351.7835	-15	28							101
102				1352.2705	20	25							102
103				1352.7515	22	24							103
104	1180.3622	5	25	1353.2279	4	7							104
105	1179.2092	-30	12										105

	0200 - 0000 446						0400 - 0200 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
0				1168.9722	4	4				1155.2816	1	5	0
1	1167.2944	5	4	1169.8138	4	4							1
2	1166.4580	3	2	1170.6567	-2	3				1156.9678	-4	14	2
3	1165.6235	2	4	1171.5006	-16	9	1151.9260	11	11	1157.8138	1	5	3
4	1164.7906	-2	2	1172.3503	11	5	1151.0904	11	7	1158.6596	-8	9	4
5	1163.9592	-9	6	1173.1980	0	3	1150.2552	1	4	1159.5090	5	4	5
6	1163.1313	1	3	1174.0488	2	3	1149.4228	6	5	1160.3582	3	5	6
7	1162.3043	2	3	1174.9018	9	16	1148.5915	7	7	1161.2085	0	3	7
8	1161.4789	0	3	1175.7553	3	2	1147.7611	3	4	1162.0608	5	4	8
9	1160.6555	1	2	1176.6109	2	3				1162.9134	0	3	9
10	1159.8338	1	2	1177.4686	4	3	1146.1077	30	22	1163.7677	2	4	10
11	1159.0140	1	3	1178.3272	-1	3	1145.2791	5	3	1164.6223	-5	5	11
12	1158.1956	-2	3	1179.1880	0	3	1144.4534	-4	4	1165.4791	-1	3	12
13	1157.3792	-2	3	1180.0503	0	3	1143.6301	-2	3	1166.3360	-5	4	13
14	1156.5648	0	3	1180.9140	-3	3	1142.8079	0	3	1167.1950	2	4	14
15	1155.7517	-2	3	1181.7793	-4	3	1141.9865	-3	3	1168.0532	-7	4	15
16	1154.9405	-2	3	1182.6461	-6	6	1141.1668	1	4	1168.9137	-2	4	16
17	1154.1313	1	3	1183.5151	-1	3	1140.3465	-13	6	1169.7740	-7	5	17
18	1153.3234	0	3	1184.3853	2	3	1139.5299	1	3	1170.6364	2	5	18
19	1152.5172	0	3	1185.2562	-2	3	1138.7126	-3	3	1171.5003	20	11	19
20	1151.7125	-1	2	1186.1297	5	4	1137.8962	-7	4				20
21	1150.9096	0	3	1187.0033	1	3	1137.0818	1	3	1173.2235	-8	5	21
22	1150.1078	-3	3	1187.8782	-4	3	1136.2676	2	4	1174.0878	-2	3	22
23	1149.3077	-5	3	1188.7551	-1	3	1135.4540	1	3	1174.9518	-2	3	23
24	1148.5094	-3	2	1189.6330	-1	3	1134.6398	-13	7	1175.8162	-2	3	24
25	1147.7128	1	3	1190.5120	-1	2	1133.8285	-4	3				25
26	1146.9172	0	3	1191.3921	-2	2	1133.0172	-1	3	1177.5478	21	11	26
27	1146.1230	0	3	1192.2735	-1	2				1178.4100	-6	4	27
28	1145.3303	1	3	1193.1559	0	2	1131.3955	-2	4	1179.2756	1	3	28
29	1144.5389	1	2	1194.0390	-2	2	1130.5860	4	4	1180.1390	-13	8	29
30	1143.7483	-3	2	1194.9233	-2	2	1129.7758	1	4	1181.0058	7	4	30
31	1142.9594	-2	2	1195.8085	-2	3	1128.9664	2	3	1181.8695	-1	3	31

32	1142.1719	0	3	1196.6948	1	3	1128.1548	-21	12	1182.7340	1	5	32
33	1141.3856	2	2	1197.5815	0	2	1127.3489	12	6	1183.5985	7	4	33
34	1140.5999	-1	3	1198.4694	3	3	1126.5392	5	5	1184.4616	2	4	34
35	1139.8156	0	2	1199.3575	1	2	1125.7302	6	4	1185.3246	1	3	35
36	1139.0324	0	3	1200.2464	0	2	1124.9211	5	6	1186.1874	3	3	36
37	1138.2505	4	3	1201.1358	-1	3	1124.1119	4	6	1187.0494	3	3	37
38	1137.4689	1	3	1202.0260	-1	2	1123.3036	13	7	1187.9105	0	5	38
39	1136.6888	4	3	1202.9169	2	2	1122.4934	6	5	1188.7723	11	8	39
40	1135.9093	4	3	1203.8080	2	2	1121.6827	-5	5	1189.6317	6	5	40
41	1135.1308	5	3	1204.6993	0	3	1120.8731	-2	4	1190.4926	24	18	41
42	1134.3526	2	3	1205.5913	2	2	1120.0630	0	4	1191.3485	0	4	42
43	1133.5740	-14	9	1206.4833	1	2	1119.2522	-2	6	1192.2058	-2	4	43
44	1132.7990	0	3	1207.3757	1	2	1118.4410	-3	4	1193.0616	-8	7	44
45	1132.0234	1	3	1208.2682	0	2	1117.6298	-1	5	1193.9171	-8	6	45
46	1131.2472	-10	6	1209.1609	0	2	1116.8169	-10	6	1194.7719	-6	10	46
47	1130.4737	0	3	1210.0539	1	2	1116.0036	-18	13	1195.6245	-14	5	47
48	1129.7003	6	4	1210.9466	0	3	1115.1923	-1	7	1196.4794	11	9	48
49	1128.9263	0	2	1211.8396	1	2	1114.3775	-14	8	1197.3286	-11	5	49
50	1128.1544	11	6	1212.7329	5	6	1113.5651	4	6	1198.1799	0	7	50
51	1127.3809	2	4	1213.6250	-1	3	1112.7518	18	20	1199.0283	-7	5	51
52	1126.6084	-1	3	1214.5176	-1	2	1111.9348	1	7	1199.8778	8	7	52
53	1125.8367	0	3	1215.4101	-1	2	1111.1179	-8	14	1200.7242	4	11	53
54	1125.0651	0	3	1216.3026	2	3	1110.3006	-16	24	1201.5682	-13	19	54
55	1124.2936	-2	3	1217.1943	0	2	1109.4874	24	20	1202.4142	2	8	55
56	1123.5228	0	3	1218.0863	4	4	1108.6667	-5	11	1203.2583	9	8	56
57	1122.7519	-1	3	1218.9771	-1	3	1107.8497	8	7	1204.1012	15	14	57
58	1121.9811	-2	3	1219.8676	-5	4	1107.0305	5	7	1204.9400	-8	15	58
59	1121.2101	-7	4	1220.7582	-4	3				1205.7819	11	7	59
60	1120.4396	-7	3	1221.6482	-4	3							60
61	1119.6702	2	4	1222.5379	-2	3							61
62	1118.8992	-4	4	1223.4265	-6	4	1103.7502	12	24	1208.2964	22	18	62
63	1118.1290	-4	4	1224.3158	3	3	1102.9249	-26	17	1209.1322	23	21	63
64	1117.3607	17	10	1225.2035	1	3							64
65	1116.5887	0	7	1226.0906	0	4				1210.7989	7	14	65
66	1115.8187	4	5	1226.9772	0	8				1211.6302	-7	12	66
67	1115.0483	4	7	1227.8617	-15	8				1212.4622	-4	12	67
68	1114.2781	7	5	1228.7495	10	7				1213.2931	-3	6	68

J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
69	1113.5065	-2	8										69
70	1112.7372	12	12										70
71	1111.9655	4	5	1231.4007	5	6							71
72	1111.1936	-5	16	1232.2834	8	7							72
73	1110.4238	8	11	1233.1665	22	13							73
74	1109.6506	-11	13										74
75	1108.8829	27	17	1234.9256	0	5							75
76	1108.1096	9	10										76
77				1236.6844	5	8							77
78													78
79	1105.7935	4	11										79
80													80
81	1104.2515	26	25										81
82				1241.0635	-38	19							82
83	1102.7035	-8	7										83

	1200 - 0200 446						1200 - 1000 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
0													0
1	1293.0245	2	4	1295.5329	-3	2	1176.2578	-4	29				1
2	1292.1797	-12	7	1296.3622	-2	2	1175.4257	2	15	1179.6077	8	15	2
3	1291.3360	21	15	1297.1877	-4	2	1174.5945	0	13				3
4	1290.4836	1	2	1298.0100	-1	2				1181.2925	6	8	4
5	1289.6294	-1	2	1298.8285	-1	2	1172.9379	-2	14	1182.1396	26	22	5
6	1288.7721	1	3	1299.6432	-4	4				1182.9838	0	6	6
7	1287.9112	2	2	1300.4543	-6	3	1171.2878	-10	30	1183.8325	1	7	7
8	1287.0464	-1	2	1301.2626	0	2	1170.4661	-7	5				8
9	1286.1790	5	4	1302.0677	9	5	1169.6471	5	8	1185.5338	-7	5	9
10	1285.3063	-7	5	1302.8688	14	16				1186.3882	1	4	10
11	1284.4321	0	2				1168.0116	1	4	1187.2437	4	5	11
12	1283.5538	2	2	1304.4573	-4	4	1167.1954	-11	4	1188.1013	12	7	12
13	1282.6720	3	2	1305.2472	-2	2	1166.3834	1	4	1188.9588	3	5	13

14	1281.7865	1	2	1306.0332	-3	2	1165.5720	2	6	1189.8192	8	6	14
15	1280.8967	-9	6	1306.8160	0	2	1164.7630	10	15	1190.6799	0	4	15
16	1280.0054	1	2	1307.5950	1	2				1191.5429	0	4	16
17	1279.1099	2	2	1308.3708	6	14				1192.4073	0	4	17
18	1278.2107	1	2	1309.1403	-15	18	1162.3426	1	5	1193.2738	6	4	18
19	1277.3081	0	2	1309.9102	4	3	1161.5394	1	5	1194.1407	3	4	19
20	1276.4022	1	2	1310.6747	5	2	1160.7381	5	4	1195.0088	-3	3	20
21	1275.4921	-7	6	1311.4348	-1	3	1159.9372	-3	4	1195.8784	-6	5	21
22	1274.5808	7	4	1312.1927	7	4	1159.1392	3	5	1196.7504	2	4	22
23	1273.6642	2	3	1312.9462	8	6	1158.3419	1	5	1197.6214	-13	11	23
24	1272.7441	-4	4	1313.6957	5	5	1157.5462	0	7	1198.4961	-3	5	24
25	1271.8218	1	3	1314.4421	7	5	1156.7519	-1	3	1199.3725	13	17	25
26	1270.8958	4	2	1315.1841	2	2	1155.9598	5	5	1200.2465	-7	4	26
27	1269.9649	-10	6	1315.9234	7	4	1155.1678	-1	4	1201.1243	1	11	27
28	1269.0333	3	2	1316.6585	6	5	1154.3774	-4	5	1202.0022	-1	3	28
29	1268.0966	-1	2	1317.3891	-4	6	1153.5900	9	7	1202.8821	7	5	29
30	1267.1568	-4	2	1318.1175	1	3	1152.8016	0	5	1203.7609	-4	4	30
31	1266.2142	-1	2	1318.8419	3	2	1152.0145	-9	10	1204.6425	3	5	31
32	1265.2680	-1	2	1319.5623	2	2	1151.2302	-1	4	1205.5242	3	4	32
33	1264.3185	-1	2	1320.2775	-15	18	1150.4466	2	4	1206.4051	-13	6	33
34	1263.3657	-1	2	1320.9920	-3	3	1149.6629	-7	6	1207.2900	3	7	34
35	1262.4095	-2	2	1321.7019	1	3	1148.8830	12	8	1208.1740	4	4	35
36	1261.4501	-2	2	1322.4072	-5	4	1148.1011	0	5	1209.0581	-1	5	36
37	1260.4876	0	2	1323.1094	-5	4	1147.3215	1	6	1209.9445	11	11	37
38	1259.5217	0	2	1323.8085	0	2	1146.5428	2	6	1210.8287	-4	4	38
39	1258.5524	-1	2	1324.5029	-5	4	1145.7653	6	7	1211.7157	5	5	39
40	1257.5800	-1	2	1325.1940	-6	4	1144.9880	3	7	1212.6013	-5	10	40
41										1213.4870	-18	15	41
42	1255.6255	0	2	1326.5661	2	2	1143.4357	-3	8	1214.3754	-7	7	42
43	1254.6424	-10	6	1327.2456	-5	3	1142.6605	-7	12				43
44	1253.6581	1	3	1327.9224	-2	2	1141.8862	-10	10	1216.1521	7	5	44
45	1252.6700	6	4	1328.5954	1	2	1141.1133	-4	7				45
46	1251.6774	-2	2	1329.2665	21	13				1217.9273	-1	8	46
47	1250.6827	1	3	1329.9294	-5	2				1218.8161	6	7	47
48	1249.6825	-18	27	1330.5915	-1	2	1138.7975	8	7	1219.7045	9	9	48
49	1248.6829	0	6	1331.2493	-3	2	1138.0254	0	6	1220.5910	-6	9	49
50	1247.6786	3	3	1331.9044	5	3	1137.2555	11	13				50

51	1246.6707	2	2	1332.5544	-1	3	1136.4834	-4	9	1222.3657	-16	12	51
52	1245.6597	2	2	1333.2013	-2	2	1135.7127	-8	11	1223.2556	7	11	52
53	1244.6453	0	2	1333.8445	-2	3				1224.1411	-11	11	53
54	1243.6276	-3	3	1334.4844	2	3	1134.1743	5	11				54
55	1242.6076	2	3	1335.1197	-2	2	1133.4035	-7	10				55
56	1241.5846	9	8	1335.7524	4	3	1132.6342	-6	7	1226.8033	11	12	56
57	1240.5568	0	3	1336.3807	4	3	1131.8648	-7	10	1227.6885	5	14	57
58	1239.5268	0	3	1337.0056	6	4	1131.0968	5	15				58
59	1238.4936	0	3	1337.6281	23	25							59
60	1237.4564	-8	10	1338.2434	4	3				1230.3424	1	12	60
61	1236.4176	-1	5	1338.8564	0	4	1128.7898	10	17	1231.2256	-3	11	61
62	1235.3748	-2	4	1339.4663	3	4	1128.0203	7	8	1232.1063	-26	30	62
63	1234.3291	0	4	1340.0719	0	4							63
64				1340.6754	13	6	1126.4798	-10	21				64
65	1232.2280	1	3	1341.2738	14	8							65
66	1231.1735	10	9	1341.8696	26	25							66
67	1230.1140	0	4	1342.4581	3	5							67
68	1229.0524	1	5	1343.0457	9	7							68
69				1343.6279	-1	6							69
70	1226.9190	-4	5	1344.2069	-6	6							70
71													71
72	1224.7737	-1	7	1345.3545	-3	4							72
73	1223.6943	-19	16										73
74	1222.6150	-5	6	1346.4860	-8	6							74
75	1221.5303	-12	12	1347.0464	-6	6							75
76	1220.4428	-15	25	1347.6024	-9	7							76
77	1219.3544	4	6	1348.1565	7	8							77
78	1218.2595	-9	8	1348.7049	6	10							78
79	1217.1639	3	7	1349.2486	-4	7							79
80	1216.0634	-1	14	1349.7879	-18	19							80
81													81
82	1213.8548	10	7	1350.8593	1	10							82
83													83
84	1211.6290	-20	10	1351.9120	-9	14							84
85	1210.5175	29	22	1352.4334	-3	13							85
86				1352.9526	21	21							86
87													87

88	1207.1487	27	25	1353.9733	14	12							88
89	1206.0161	-3	16										89

	1001 - 0001 446						1400 - 0400 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
0	,			1257.8917	13	15							0
1				1258.7144	0	11							1
2							1296.6803	-27	24				2
3													3
4	1253.7167	-5	9							1302.5221	19	21	4
5	1252.8702	-17	12				1294.1239	-26	6	1303.3412	19	24	5
6	1252.0234	2	5	1262.7832	22	15				1304.1550	3	5	6
7	1251.1720	11	7	1263.5837	1	5	1292.4040	0	7	1304.9659	-4	4	7
8	1250.3144	-7	5	1264.3829	3	5	1291.5382	9	7	1305.7731	-12	7	8
9				1265.1784	3	4	1290.6691	20	17				9
10	1248.5922	-7	8	1265.9701	1	5	1289.7913	-20	14				10
11										1308.1782	26	23	11
12	1246.8567	0	7	1267.5431	2	8	1288.0370	20	21	1308.9688	3	5	12
13	1245.9840	6	4	1268.3246	5	9	1287.1516	10	5	1309.7578	1	5	13
14	1245.1064	-2	3	1269.1014	-2	5	1286.2633	7	4				14
15				1269.8756	1	4	1285.3716	4	4				15
16	1243.3405	-20	20	1270.6451	-7	5	1284.4760	-2	4	1312.1022	-4	6	16
17	1242.4561	8	4				1283.5756	-22	15	1312.8772	5	5	17
18	1241.5663	17	12	1272.1752	-4	6				1313.6478	8	4	18
19	1240.6700	-4	4	1272.9352	1	4	1281.7702	-3	4	1314.4131	-5	4	19
20	1239.7724	-4	4	1273.6915	5	9	1280.8621	4	5				20
21	1238.8712	-5	4	1274.4440	7	5	1279.9500	5	5	1315.9378	24	11	21
22	1237.9663	-8	5	1275.1925	6	4	1279.0333	-6	6				22
23	1237.0581	-11	6							1317.4413	-7	4	23
24	1236.1474	-4	3	1276.6774	-10	6	1277.1925	1	5	1318.1894	-2	5	24
25	1235.2331	1	3	1277.4162	0	3	1276.2661	-5	7	1318.9309	-26	16	25
26				1278.1498	-6	14	1275.3379	5	7	1319.6741	5	6	26

27	1233.3930	-1	3	1278.8817	8	6	1274.4062	13	10	1320.4099	1	6	27
28	1232.4685	5	4	1279.6076	-2	3	1273.4693	3	5	1321.1425	2	3	28
29	1231.5415	19	14	1280.3311	0	4							29
30				1281.0505	-3	3	1271.5871	-1	5				30
31	1229.6717	-8	11				1270.6431	18	18	1323.3191	21	17	31
32	1228.7341	2	4	1282.4788	-4	4	1269.6911	-10	4	1324.0339	-4	4	32
33	1227.7928	9	7	1283.1879	-1	5	1268.7389	-7	5	1324.7474	-5	4	33
34				1283.8900	-31	18	1267.7841	2	4	1325.4582	6	4	34
35	1225.8980	1	5	1284.5938	-8	6	1266.8239	-9	5				35
36	1224.9460	2	4				1265.8631	7	11				36
37	1223.9905	0	4	1285.9865	-2	4	1264.8969	2	9	1327.5639	0	5	37
38	1223.0321	3	4				1263.9306	28	23	1328.2571	-13	9	38
39	1222.0696	-1	4	1287.3649	7	6				1328.9498	7	7	39
40	1221.1054	10	7							1329.6380	21	22	40
41	1220.1375	17	19	1288.7286	14	10				1330.3187	-2	8	41
42	1219.1627	-11	10	1289.4036	3	5	1260.0215	25	14	1330.9976	-5	7	42
43	1218.1897	11	9	1290.0772	15	6	1259.0341	5	5	1331.6738	3	4	43
44							1258.0454	5	7				44
45	1216.2320	36	17	1291.4097	1	5	1257.0519	-9	9	1333.0108	-18	12	45
46							1256.0570	-4	9	1333.6782	19	12	46
47	1214.2547	-4	16				1255.0584	-3	8	1334.3367	5	7	47
48				1293.3820	-12	11							48
49	1212.2682	-8	10				1253.0499	-12	26				49
50	1211.2722	11	15				1252.0436	14	7				50
51	1210.2691	-8	7	1295.3240	-1	7							51
52	1209.2650	-6	8				1250.0167	26	22				52
53				1296.5990	-9	9				1338.2131	-1	7	53
54	1207.2478	3	6	1297.2306	-18	11							54
55	1206.2325	-13	13				1246.9485	26	23				55
56							1245.9155	-5	5	1340.0990	10	19	56
57				1299.1088	6	7	1244.8818	-7	29	1340.7176	-5	6	57
58	1203.1735	-2	8							1341.3336	-5	7	58
59	1202.1471	-3	5										59
60													60
61	1200.0868	11	14							1343.1544	-29	20	61
62	1199.0507	5	13	1302.1644	21	21				1343.7566	1	11	62
63	1198.0137	19	25	1302.7645	21	22				1344.3521	6	9	63

64	1196.9678	-25	25							1344.9434	12	12	64
65	1195.9255	-3	9										65
66	1194.8788	5	11										66
67													67
68	1192.7726	-18	20	1305.7065	-26	20							68
69	1191.7168	-13	22										69
70	1190.6599	11	14										70
71													71
72	1188.5314	-2	15										72
73	1187.4651	13	19										73
74													74
75													75
76	1184.2413	-19	25										76
77	1183.1664	24	26										77

	1110 e - 0110 e 446						1110 f - 0110 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
1				1293.1655	13	11				1293.1655	-26	11	1
2	1289.8163	-14	11	1293.9941	18	11	1289.8163	16	11				2
3	1288.9710	-15	14				1288.9710	26	14				3
4	1288.1203	-36	15	1295.6395	14	6	1288.1203	14	15	1295.6487	-8	11	4
5				1296.4566	7	2				1296.4699	-3	5	5
6	1286.4123	-41	28	1297.2707	6	3	1286.4123	19	28	1297.2876	-1	3	6
7	1285.5547	-29	23	1298.0812	2	3	1285.5547	33	23	1298.1020	0	3	7
8				1298.8887	3	2	1284.6904	11	9	1298.9129	-2	3	8
9	1283.8254	-44	26	1299.6929	6	3	1283.8254	14	26	1299.7196	-13	14	9
10	1282.9577	-31	28	1300.4927	0	3	1282.9577	22	28	1300.5254	-1	3	10
11	1282.0852	-32	27	1301.2898	1	3	1282.0852	13	27	1301.3268	-1	3	11
12	1281.2104	-23	12	1302.0833	1	3	1281.2104	12	12	1302.1251	1	3	12
13	1280.3313	-23	10	1302.8718	-15	15	1280.3313	0	10	1302.9198	-2	3	13
14	1279.4504	-7	6	1303.6607	9	4	1279.4504	1	6	1303.7116	0	3	14
15	1278.5656	3	5	1304.4432	3	2	1278.5656	-6	5	1304.5000	-1	3	15

16	1277.6770	9	10	1305.2226	1	2	1277.6770	-19	10	1305.2831	-22	11	16
17	1276.7845	10	5	1305.9986	0	2				1306.0675	2	2	17
18	1275.8882	5	7	1306.7714	2	2				1306.8456	-4	3	18
19	1274.9910	26	18	1307.5402	-2	3				1307.6218	3	3	19
20	1274.0862	3	4	1308.3058	-2	3	1274.0989	-2	4	1308.3944	7	9	20
21	1273.1805	5	2	1309.0682	0	3	1273.1958	-6	6	1309.1623	-4	3	21
22	1272.2713	5	4	1309.8275	7	6	1272.2907	0	3	1309.9282	-3	3	22
23	1271.3587	4	4				1271.3818	-1	2	1310.6906	-4	3	23
24	1270.4425	0	3	1311.3333	-3	4	1270.4702	1	2	1311.4501	-2	3	24
25	1269.5238	4	3	1312.0816	-1	2	1269.5536	-16	9	1312.2063	0	3	25
26	1268.6012	2	2	1312.8260	-3	3	1268.6373	0	3	1312.9588	-3	3	26
27	1267.6752	-2	4	1313.5673	-1	3	1267.7161	-3	3	1313.7085	-2	3	27
28	1266.7463	-1	3	1314.3050	0	2	1266.7921	-3	3	1314.4548	-2	2	28
29	1265.8139	-2	3	1315.0390	-1	2	1265.8650	-5	3	1315.1979	-1	2	29
30	1264.8786	0	3	1315.7699	2	3	1264.9352	-3	3	1315.9379	0	2	30
31	1263.9397	-2	3	1316.4964	-4	3	1264.0024	-2	2	1316.6740	-5	4	31
32	1262.9978	-1	3	1317.2201	-2	2	1263.0667	0	3	1317.4076	-3	2	32
33	1262.0522	-4	3	1317.9401	-3	2	1262.1275	-4	3	1318.1378	-2	2	33
34	1261.1040	-1	2	1318.6569	0	3	1261.1859	-1	3	1318.8648	-2	3	34
35	1260.1516	-8	5	1319.3697	-2	3	1260.2411	-2	3	1319.5896	9	5	35
36				1320.0789	-5	5	1259.2935	-1	3	1320.3091	-1	3	36
37	1258.2411	18	11	1320.7851	-2	3	1258.3428	-2	3	1321.0264	0	3	37
38	1257.2781	2	3	1321.4881	4	4	1257.3894	-1	3	1321.7403	-2	3	38
39	1256.3134	1	3	1322.1866	-1	2	1256.4339	8	5	1322.4517	3	4	39
40	1255.3454	-2	3	1322.8822	1	3	1255.4739	0	2	1323.1593	3	4	40
41	1254.3745	-1	2	1323.5724	-15	8	1254.5115	-2	3	1323.8635	0	3	41
42	1253.4003	-2	2	1324.2621	-2	2	1253.5464	-4	3	1324.5650	3	3	42
43	1252.4232	0	2	1324.9470	-1	2	1252.5783	-6	5	1325.2631	3	3	43
44	1251.4428	0	2	1325.6284	-1	2				1325.9577	0	2	44
45	1250.4596	4	3	1326.3066	3	3	1250.6349	1	2	1326.6493	-1	2	45
46	1249.4725	0	2	1326.9808	3	3	1249.6580	-5	19	1327.3380	0	2	46
47	1248.4827	0	2	1327.6514	1	2	1248.6810	15	11	1328.0224	-10	12	47
48	1247.4898	1	2	1328.3185	-1	2	1247.6981	4	3	1328.7060	4	3	48
49	1246.4935	-2	2	1328.9824	1	2	1246.7137	6	3	1329.3854	7	4	49
50	1245.4943	-2	2	1329.6425	-1	2	1245.7258	0	3	1330.0610	3	3	50
51	1244.4922	0	2	1330.2992	-1	2	1244.7357	-1	2	1330.7334	-1	3	51
52	1243.4874	5	3	1330.9526	1	2	1243.7433	2	2	1331.4034	2	3	52

53	1242.4783	-2	2	1331.6024	2	2	1242.7477	0	2	1332.0699	1	2	53
54	1241.4670	-1	2	1332.2483	-2	3	1241.7498	2	2	1332.7330	-3	2	54
55	1240.4527	1	2	1332.8920	8	4	1240.7489	0	2	1333.3939	2	2	55
56	1239.4349	-1	2				1239.7456	1	2	1334.0512	1	2	56
57	1238.4153	8	5	1334.1652	-9	6	1238.7395	0	3	1334.7046	-7	6	57
58	1237.3908	-1	2	1334.7989	5	3	1237.7305	-5	4	1335.3566	1	2	58
59	1236.3657	13	6	1335.4272	0	2	1236.7200	1	2	1336.0049	2	2	59
60	1235.3349	1	2	1336.0522	-3	2	1235.7062	0	2	1336.6508	10	5	60
61	1234.3024	1	3				1234.6899	-1	2	1337.2921	1	2	61
62	1233.2671	3	2	1337.2922	-4	3	1233.6714	2	2	1337.9309	-2	3	62
63	1232.2284	0	2	1337.9082	7	3	1232.6500	0	2	1338.5668	-4	3	63
64	1231.1871	0	2	1338.5193	4	2	1231.6264	0	2	1339.2004	0	2	64
65	1230.1426	-2	3	1339.1273	4	3	1230.6014	11	6	1339.8311	5	5	65
66	1229.0958	2	2	1339.7314	0	2	1229.5718	1	3	1340.4584	6	3	66
67	1228.0455	0	3	1340.3327	2	2	1228.5406	-2	3	1341.0820	-2	3	67
68	1226.9924	-2	3	1340.9285	-16	12	1227.5074	-1	3	1341.7034	-2	4	68
69	1225.9363	-4	3	1341.5217	-27	24	1226.4718	-1	3	1342.3216	-5	4	69
70	1224.8781	0	3	1342.1149	-3	3	1225.4337	-2	3	1342.9377	-1	4	70
71	1223.8178	12	5	1342.7024	-1	3	1224.3934	-2	3	1343.5503	-3	4	71
72	1222.7530	7	4	1343.2864	-1	3	1223.3511	0	3	1344.1603	-2	3	72
73	1221.6851	-1	4	1343.8675	4	4	1222.3063	-1	3				73
74	1220.6149	-4	4	1344.4440	-3	3	1221.2595	1	4	1345.3716	-4	4	74
75	1219.5426	0	4	1345.0184	3	4	1220.2114	11	9	1345.9729	-7	5	75
76	1218.4669	-3	4	1345.5874	-12	8				1346.5729	4	4	76
77	1217.3887	-3	4	1346.1554	-2	5	1218.1017	-38	19				77
78				1346.7188	-6	5				1347.7615	-5	20	78
79	1215.2246	0	4	1347.2790	-8	8	1215.9919	-6	5	1348.3526	-1	4	79
80	1214.1376	-8	6	1347.8368	0	4	1214.9332	3	4	1348.9406	-2	4	80
81	1213.0486	-9	8	1348.3898	-8	11	1213.8712	-1	4	1349.5262	-1	4	81
82	1211.9580	0	5	1348.9406	-4	4	1212.8075	-3	5	1350.1087	-4	6	82
83	1210.8634	-4	6	1349.4880	-2	6	1211.7417	-6	13	1350.6895	1	5	83
84	1209.7670	-1	5	1350.0316	-4	10	1210.6747	-3	5	1351.2668	-4	7	84
85	1208.6694	17	13	1350.5718	-8	10	1209.6057	-1	7	1351.8426	2	5	85
86				1351.1107	7	9	1208.5348	0	6	1352.4152	1	5	86
87	1206.4616	2	7	1351.6441	0	6	1207.4603	-17	8	1352.9845	-9	9	87
88	1205.3528	-17	13	1352.1774	24	28	1206.3886	12	10	1353.5529	-4	13	88
89	1204.2449	-2	24	1352.7022	-4	4	1205.3125	13	15	1354.1193	5	8	89

J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
90	1203.1340	8	6	1353.2277	6	7				1354.6814	-5	6	90
91				1353.7488	4	7	1203.1551	13	11	1355.2424	-3	7	91
92				1354.2649	-16	22				1355.8024	11	6	92
93				1354.7820	5	12	1200.9908	6	13	1356.3583	7	11	93
94				1355.2920	-14	22	1199.9075	14	12				94
95				1355.8024	3	8				1357.4672	37	26	95
96													96
97				1356.8110	7	13							97
98				1357.3109	11	15							98
99				1357.8096	33	26							99
100				1358.3033	35	26							100

	0310 e - 0110 e 446						0310 f - 0110 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
1				1161.9823	59	18				1161.9823	-15	18	1
2	1158.6203	-11	10	1162.8175	3	5	1158.6203	7	10	1162.8299	-5	6	2
3	1157.7848	1	6	1163.6591	4	3	1157.7848	7	6	1163.6784	-8	4	3
4	1156.9502	14	5	1164.5019	8	4	1156.9502	-7	5	1164.5303	2	3	4
5	1156.1174	37	25	1165.3442	0	4	1156.1174	-24	25	1165.3829	-4	3	5
6	1155.2812	17	9	1166.1882	1	3				1166.2384	-2	3	6
7	1154.4467	7	3	1167.0329	1	4	1154.4641	-3	2	1167.0960	-1	2	7
8	1153.6131	-4	4	1167.8781	-1	3	1153.6400	-1	3	1167.9557	0	3	8
9	1152.7819	2	3	1168.7250	7	5	1152.8177	-3	3	1168.8175	0	3	9
10	1151.9510	3	3	1169.5727	15	8	1151.9978	-3	2	1169.6813	-1	2	10
11	1151.1207	1	4	1170.4191	4	2	1151.1805	1	3	1170.5474	0	3	11
12	1150.2913	0	3	1171.2674	4	3	1150.3649	0	3	1171.4153	-2	2	12
13	1149.4630	2	2	1172.1160	0	3	1149.5511	-6	3	1172.2855	-2	2	13
14	1148.6347	-4	4	1172.9660	4	3	1148.7410	4	4	1173.1578	-2	2	14
15	1147.8081	-1	3	1173.8162	3	3	1147.9315	-3	2	1174.0332	10	7	15
16	1146.9822	1	3	1174.6672	3	2	1147.1251	0	2				16
17	1146.1568	0	3	1175.5178	-6	5	1146.3202	-4	3	1175.7865	-3	3	17
18	1145.3311	-11	10	1176.3709	3	3	1145.5179	-3	3	1176.6671	0	3	18

19	1144.5084	-1	2	1177.2237	3	3	1144.7180	-1	3	1177.5480	-14	7	19
20	1143.6856	1	2	1178.0768	1	2	1143.9198	-2	2	1178.4334	-2	3	20
21	1142.8633	1	3	1178.9307	1	2	1143.1241	0	3	1179.3191	-4	3	21
22	1142.0420	3	2	1179.7850	0	3	1142.3302	-1	3	1180.2072	-5	3	22
23	1141.2205	-5	4	1180.6400	1	2	1141.5386	0	3	1181.0975	0	3	23
24	1140.4011	2	3	1181.4952	-1	3	1140.7489	-1	3	1181.9897	5	4	24
25	1139.5823	7	5	1182.3514	2	3	1139.9610	-4	3	1182.8823	1	3	25
26	1138.7638	8	5	1183.2076	1	3	1139.1758	-1	2	1183.7773	-1	2	26
27	1137.9448	-2	2	1184.0644	2	3	1138.3921	-3	2	1184.6754	4	3	27
28	1137.1279	2	3	1184.9216	2	3	1137.6110	1	3	1185.5736	-1	2	28
29	1136.3110	-1	2	1185.7788	-1	3	1136.8315	1	3	1186.4741	0	2	29
30	1135.4956	5	4	1186.6370	2	3	1136.0538	-1	3	1187.3761	-1	3	30
31	1134.6797	-1	3	1187.4946	-3	4	1135.2785	2	2	1188.2793	-1	2	31
32	1133.8653	3	3	1188.3532	-2	3	1134.5047	1	3	1189.1857	6	4	32
33	1133.0508	-1	3	1189.2121	-1	2	1133.7324	-4	4	1190.0921	1	2	33
34	1132.2370	-3	3	1190.0718	6	4	1132.9632	3	3	1191.0002	-1	2	34
35	1131.4263	20	10	1190.9304	-1	2	1132.1952	4	5	1191.9103	2	2	35
36	1130.6118	0	2	1191.7896	-3	3	1131.4266	-20	13	1192.8209	-4	3	36
37	1129.7999	0	2	1192.6496	0	3	1130.6635	-6	4	1193.7334	-6	5	37
38	1128.9884	-1	4	1193.5092	-1	2	1129.9014	1	3	1194.6485	6	4	38
39	1128.1775	-1	4	1194.3693	1	3	1129.1405	2	2	1195.5634	1	2	39
40	1127.3672	1	3	1195.2288	-4	2	1128.3814	4	3	1196.4795	-2	3	40
41	1126.5572	1	3	1196.0888	-4	3	1127.6236	3	2	1197.3976	0	2	41
42	1125.7475	-1	4	1196.9492	-1	3	1126.8675	3	3	1198.3169	3	2	42
43	1124.9376	-8	5	1197.8095	1	2	1126.1128	0	3	1199.2368	1	3	43
44	1124.1295	-2	3	1198.6691	-3	3	1125.3598	0	3	1200.1577	-2	3	44
45	1123.3216	3	3	1199.5293	-2	3	1124.6092	8	4	1201.0803	1	2	45
46	1122.5129	-4	4	1200.3887	-7	3	1123.8583	3	3	1202.0035	2	4	46
47	1121.7059	2	3	1201.2490	-2	3	1123.1102	2	3				47
48	1120.8982	-1	3	1202.1088	-1	3	1122.3630	2	3	1203.8525	0	3	48
49	1120.0916	3	3	1202.9686	1	3	1121.6170	-1	3	1204.7779	-6	3	49
50	1119.2847	1	4	1203.8281	2	4	1120.8728	2	3	1205.7057	6	3	50
51	1118.4784	3	4				1120.1289	-5	4	1206.6329	4	4	51
52	1117.6717	-2	4	1205.5461	2	3	1119.3868	-7	3	1207.5604	-2	3	52
53	1116.8665	6	5	1206.4052	7	4	1118.6461	-6	4	1208.4891	-2	[illegible]	53
54	1116.0600	-1	4	1207.2632	3	5	1117.9069	-1	4	1209.4194	9	10	54
55	1115.2550	5	6	1208.1212	3	4	1117.1682	-2	4	1210.3478	-4	4	55

J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
56	1114.4485	-6	6	1208.9789	3	5	1116.4306	-2	10	1211.2774	-9	8	56
57	1113.6442	4	6	1209.8365	6	4	1115.6927	-16	10	1212.2085	-4	8	57
58	1112.8380	-7	4	1210.6930	2	4	1114.9586	0	4	1213.1399	2	4	58
59	1112.0331	-6	8	1211.5499	6	6	1114.2235	-3	11	1214.0704	-4	5	59
60	1111.2270	-18	5	1212.4063	10	6	1113.4891	-8	9	1215.0015	-5	9	60
61	1110.4240	0	7	1213.2598	-11	8	1112.7518	-49	16	1215.9341	7	8	61
62	1109.6200	7	5	1214.1167	7	10	1112.0203	-39	14	1216.8640	-8	5	62
63	1108.8157	11	11				1111.2927	4	7	1217.7978	16	12	63
64	1108.0105	5	6	1215.8257	12	11	1110.5605	-6	13				64
65				1216.6789	9	8	1109.8313	9	7	1219.6578	-8	18	65
66				1217.530[illegible]	-3	9	1109.1021	19	15	1220.5908	13	8	66
67	1105.5966	3	7	1218.3810	-22	18							67
68	1104.7931	13	12	1219.2337	-11	8	1107.6429	20	17				68
69							1106.9115	-2	13				69
70	1103.1811	-15	18				1106.1838	11	9				70
71	1102.3788	8	9										71
72	1101.5743	9	24										72
73	1100.7671	-16	18	1223.4790	-44	14	1103.9965	2	9				73
74													74
75							1102.5381	-5	15				75

	1220 e - 0220 e 446						1220 f - 0220 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
2				1299.5558	0	3				1299.5558	0	3	2
3	1294.5242	3	4	1300.3832	-1	3	1294.5242	3	4	1300.3832	-1	3	3
4	1293.6736	-5	16	1301.2074	-2	3	1293.6736	-5	16	1301.2074	-1	3	4
5	1292.8207	-4	4	1302.0285	-1	3	1292.8207	-5	4	1302.0285	-1	3	5
6	1291.9654	4	6	1302.8470	5	5	1291.9654	4	6	1302.8470	6	5	6
7	1291.1055	-2	4	1303.6608	-3	4	1291.1055	-2	4	1303.6608	-2	4	7
8	1290.2430	-1	3	1304.4726	0	5	1290.2430	-3	3	1304.4726	2	5	8
9	1289.3775	0	3	1305.2826	18	21	1289.3775	-2	3	1305.2826	20	21	9
10	1288.5090	4	3	1306.0853	-5	4	1288.5090	1	3	1306.0853	-3	4	10

11	1287.6351	-15	12	1306.8879	4	6	1287.6351	-20	12	1306.8879	6	6	11
12	1286.7615	0	4	1307.6848	-13	8	1286.7615	-5	4	1307.6848	-10	8	12
13	1285.8833	1	4	1308.4812	-2	3	1285.8833	-6	4	1308.4812	2	3	13
14				1309.2734	-1	4				1309.2734	3	4	14
15	1284.1172	1	5	1310.0621	-2	3	1284.1172	-10	5	1310.0621	3	3	15
16				1310.8483	4	9				1310.8483	9	9	16
17	1282.3392	8	4	1311.6293	-10	6	1282.3392	-9	4	1311.6293	-4	6	17
18	1281.4453	9	4	1312.4085	-9	6	1281.4453	-11	4	1312.4085	-3	6	18
19	1280.5484	12	4	1313.1847	-5	4	1280.5484	-13	4	1313.1847	1	4	19
20	1279.6485	16	6	1313.9573	-5	4	1279.6485	-13	6	1313.9573	1	4	20
21	1278.7457	23	7	1314.7270	-2	4	1278.7457	-12	7	1314.7270	5	4	21
22	1277.8392	24	6	1315.4935	2	7	1277.8392	-17	6	1315.4935	9	7	22
23	1276.9291	20	9	1316.2556	-5	4	1276.9291	-27	9	1316.2556	2	4	23
24	1276.0147	4	5	1317.0149	-8	6				1317.0149	-1	6	24
25	1275.1006	23	20	1317.7716	-4	4	1275.1006	-39	20	1317.7716	2	4	25
26	1274.1813	21	6	1318.5246	-4	4				1318.5246	1	4	26
27	1273.2619	48	14	1319.2744	-3	4	1273.2619	-33	14	1319.2744	1	4	27
28	1272.3345	27	9	1320.0209	-3	4				1320.0209	0	4	28
29	1271.4054	20	7	1320.7650	6	4				1320.7650	7	4	29
30	1270.4710	-9	10	1321.5042	-1	4				1321.5042	-2	4	30
31	1269.5378	5	6	1322.2416	7	4				1322.2416	3	4	31
32	1268.6012	16	3	1322.9745	3	4				1322.9745	-4	4	32
33	1267.6599	11	3	1323.7051	9	4	1267.6751	2	4	1323.7051	-2	4	33
34	1266.7156	6	4	1324.4312	3	8	1266.7330	3	7	1324.4312	-12	8	34
35	1265.7699	18	5	1325.1566	23	8	1265.7879	3	5	1325.1566	3	8	35
36	1264.8177	-4	8	1325.8772	28	11	1264.8392	-4	3	1325.8772	2	11	36
37	1263.8644	-6	7	1326.5913	1	18	1263.8882	-5	2	1326.5913	-31	18	37
38	1262.9098	9	9	1327.3064	17	10	1262.9335	-13	6	1327.3064	-22	10	38
39	1261.9500	3	3							1328.0201	5	6	39
40	1260.9880	6	2	1328.7237	20	8	1261.0182	-2	4				40
41	1260.0220	-2	4	1329.4278	26	9	1260.0562	4	4				41
42	1259.0538	0	3	1330.1284	30	22	1259.0904	0	2				42
43	1258.0822	-3	4	1330.82[illegible]1	28	20	1258.1223	2	3				43
44	1257.1085	4	2	1331.5[illegible]4	16	6	1257.1507	-3	2				44
45	1256.1310	3	3	1332.2066	5	5	1256.1768	-2	2	1332.2177	-2	3	45
46	1255.1502	-1	2	1332.8928	-1	4	1255.2003	1	2	1332.9066	2	5	46
47	1254.1666	-3	2	1333.5791	26	14	1254.2207	1	2				47

48	1253.1800	-5	2	1334.2569	2	3	1253.2382	0	2	1334.2741	3	3	48
49	1252.1908	-3	2	1334.9340	4	2	1252.2525	-5	3	1334.9526	-1	2	49
50	1251.1983	-5	2	1335.6072	1	3	1251.2652	1	2	1335.6288	4	3	50
51	1250.2032	-3	3	1336.2776	3	4	1250.2745	1	2	1336.3008	-2	3	51
52	1249.2045	-7	5	1336.9436	-6	4	1249.2811	1	3	1336.9703	-1	2	52
53	1248.2034	-6	3	1337.6075	-2	2	1248.2848	0	3	1337.6358	-9	5	53
54	1247.1993	-5	3	1338.2676	-3	2	1247.2876	16	8	1338.2997	0	2	54
55	1246.1925	-2	3	1338.9241	-6	3	1246.2841	-3	3	1338.9596	-1	3	55
56	1245.1798	-29	18	1339.5779	-3	3	1245.2804	2	3	1339.6168	3	3	56
57	1244.1694	-4	3	1340.2279	-4	3	1244.2735	2	3	1340.2703	1	3	57
58	1243.1536	-4	3	1340.8745	-6	3							58
59	1242.1353	0	4	1341.5208	22	23	1242.2519	3	3	1341.5679	-3	3	59
60	1241.1136	-2	3	1342.1583	-4	4	1241.2361	-7	6	1342.2126	0	3	60
61	1240.0888	-6	5	1342.7951	-4	4	1240.2200	5	3	1342.8542	4	3	61
62	1239.0629	7	6	1343.4290	1	3	1239.1998	3	4	1343.4913	-7	6	62
63	1238.0310	-11	10	1344.0595	5	4	1238.1776	6	6	1344.1274	3	4	63
64	1236.9996	3	4	1344.6856	-2	4	1237.1520	0	3				64
65	1235.9645	9	6	1345.3095	3	4	1236.1250	5	5	1345.3882	0	4	65
66	1234.9259	7	4	1345.9269	-24	22	1235.0944	-1	4	1346.0141	-1	5	66
67	1233.8842	1	5	1346.5466	5	4	1234.0622	2	5	1346.6376	5	5	67
68	1232.8397	-4	8							1347.2574	3	7	68
69	1231.7947	12	5				1231.9895	-1	4	1347.8744	4	5	69
70	1230.7461	19	6	1348.3777	12	15	1230.9493	-5	4	1348.4875	-5	6	70
71	1229.6943	21	7	1348.9803	3	6	1229.9063	-13	8	1349.0989	-1	4	71
72	1228.6398	23	6	1349.5802	0	5	1228.8631	1	5	1349.7061	-9	8	72
73				1350.1783	12	5	1227.8169	8	11	1350.3142	20	23	73
74				1350.7714	7	10	1226.7653	-16	18	1350.9142	-1	6	74
75	1225.4601	24	11				1225.7138	-16	10	1351.5137	1	5	75
76	1224.3937	11	10	1351.9486	6	7	1224.6606	-10	9	1352.1101	1	5	76
77				1352.5318	0	5	1223.6036	-20	20	1352.7023	-12	9	77
78	1222.2575	27	12	1353.1133	10	7							78
79	1221.1821	-1	17	1353.6899	3	6				1353.8814	-6	10	79
80	1220.1072	1	9	1354.2641	5	8	1220.4258	16	18	1354.4682	12	14	80
81	1219.0296	1	11	1354.8340	-4	10				1355.0490	-2	7	81
82	1217.9478	-17	10	1355.4008	-11	7	1218.2913	-13	18	1355.6295	9	11	82
83	1216.8645	-27	6	1355.9636	-26	10				1356.2042	-11	13	83
84							1216.1523	-3	6	1356.7813	21	20	84

J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
85										1357.3508	4	8	85
86							1214.0054	9	9	1357.9173	-16	28	86
87							1212.9274	0	8				87
88													88
89							1210.7695	19	25				89

	0420 e - 0220 e 446						0420 f - 0220 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
2				1155.9075	23	25				1155.9075	23	25	2
3	1150.8607	9	26	1156.7515	9	7	1150.8607	9	26	1156.7515	9	7	3
4	1150.0226	-9	13	1157.5971	-3	8	1150.0226	-9	13	1157.5971	-1	8	4
5	1149.1884	0	7	1158.4460	6	11	1149.1884	0	7	1158.4460	9	11	5
6	1148.3545	-2	7	1159.2942	-6	7	1148.3545	-2	7	1159.2942	-1	7	6
7	1147.5226	2	6	1160.1448	-7	6	1147.5226	4	6	1160.1448	1	6	7
8	1146.6913	-1	6	1160.9969	-6	4	1146.6913	2	6	1160.9969	6	4	8
9	1145.8619	1	5	1161.8503	-7	4	1145.8619	6	5	1161.8503	12	4	9
10	1145.0330	-5	5	1162.7045	-13	6	1145.0330	3	5	1162.7045	13	6	10
11	1144.2068	1	6	1163.5599	-21	8	1144.2068	13	6	1163.5599	15	8	11
12	1143.3806	-8	4	1164.4170	-27	11	1143.3806	11	4	1164.4170	22	11	12
13	1142.5561	-14	6	1165.2755	-33	19	1142.5561	12	6	1165.2755	32	19	13
14	1141.7333	-19	7				1141.7333	18	7				14
15	1140.9128	-16	11				1140.9128	34	11	1166.9936	27	13	15
16				1167.8654	1	12	1140.0910	24	7	1167.8534	16	22	16
17							1139.2707	16	12				17
18	1138.4604	-11	15	1169.5970	-4	4							18
19	1137.6450	-22	16	1170.4656	-3	5	1137.6346	9	6	1170.4407	-5	9	19
20	1136.8321	-25	9	1171.3351	-10	4				1171.3062	-2	5	20
21	1136.0237	-1	4	1172.2076	-4	5	1136.0038	5	3	1172.1715	-11	13	21
22	1135.2142	-5	4	1173.0805	-11	4	1135.1905	6	4	1173.0405	7	5	22
23	1134.4064	-11	5	1173.9565	-5	3	1134.3778	1	5	1173.9083	3	3	23
24	1133.6017	-5	4	1174.8334	-9	3				1174.7771	0	5	24
25	1132.7988	-1	5	1175.7126	-8	5	1132.7568	-1	5	1175.6484	13	4	25

26	1131.9967	-7	4				1131.9488	5	3	1176.5183	2	4	26
27	1131.1978	-2	5				1131.1412	4	5	1177.3898	-1	5	27
28	1130.4002	-5	4	1178.3611	-10	3	1130.3344	0	4	1178.2633	7	3	28
29	1129.6051	-3	5	1179.2483	-6	4	1129.5292	1	5	1179.1362	2	3	29
30	1128.8113	-10	5	1180.1390	12	7	1128.7250	1	4	1180.0109	6	3	30
31	1128.0208	-6	5	1181.0277	-10	4	1127.9224	6	6	1180.8865	12	7	31
32	1127.2318	-8	4	1181.9194	-23	16	1127.1193	-5	5	1181.7626	15	8	32
33	1126.4460	-2	3	1182.8160	-8	4	1126.3180	-8	7				33
34	1125.6615	-5	4	1183.7139	-1	3	1125.5186	-2	4	1183.5150	3	4	34
35	1124.8800	-2	5	1184.6139	5	4	1124.7203	5	4				35
36				1185.5155	6	3	1123.9220	2	5				36
37	1123.3219	-17	9	1186.4189	2	4	1123.1157	9	20				37
38	1122.5484	-5	5	1187.3253	7	4	1122.3289	3	4	1187.0300	6	4	38
39	1121.7768	1	4	1188.2336	8	5	1121.5333	-1	8	1187.9094	-1	4	39
40	1121.0072	2	5	1189.1432	1	6	1120.7394	3	5	1188.7893	-7	6	40
41	1120.2398	1	6	1190.0588	31	17	1119.9461	5	4	1189.6704	-6	5	41
42	1119.4767	18	7	1190.9717	12	4	1119.1542	12	12	1190.5526	2	7	42
43	1118.7137	10	5	1191.8887	12	7	1118.3614	2	11	1191.4340	-1	5	43
44	1117.9535	5	12				1117.5701	0	13	1192.3154	-8	7	44
45	1117.1975	17	9				1116.7806	8	9	1193.1973	-13	9	45
46				1194.6493	-23	19	1115.9902	-1	7	1194.0806	-7	13	46
47	1115.6917	27	19							1194.9635	-7	9	47
48	1114.9421	28	16	1196.5056	7	7	1114.4138	6	8	1195.8471	-2	6	48
49	1114.1911	-10	25	1197.4352	5	6	1113.6250	-7	9	1196.7310	5	12	49
50	1113.4483	9	6	1198.3670	6	8	1112.8379	-9	4				50
51	1112.7063	12	10	1199.3013	13	10	1112.0513	-11	8	1198.4961	-12	5	51
52	1111.9654	3	4				1111.2644	-22	13				52
53	1111.2275	0	4	1201.1705	-22	18	1110.4818	4	9				53
54				1202.1086	-30	4	1109.6957	-9	10				54
55	1109.7597	6	14	1203.0541	20	17	1108.9134	11	14				55
56	1109.0271	-10	12	1203.9946	5	11	1108.1298	14	18	1202.9150	10	11	56
57	1108.2968	-23	8	1204.9400	26	17	1107.3442	-7	11				57
58				1205.8835	15	6	1106.5625	7	6				58
59				1206.8293	17	8							59
60							1104.9958	-8	19				60
61													61
62							1103.4323	-1	17	1208.2086	7	16	62

J										R Obs	O-C	Unc	J
63										1209.0896	6	27	63
64										1209.9706	10	10	64

	1310 e - 0310 e 446						1310 f - 0310 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
1													1
2				1299.6432	-5	3							2
3													3
4				1301.2897	6	4	1293.7595	4	3	1301.3076	-1	8	4
5				1302.1047	-15	18	1292.9053	19	20				5
6	1292.0603	17	10	1302.9198	1	3	1292.0445	2	3	1302.9475	-1	4	6
7	1291.1957	-19	9				1291.1816	-2	8	1303.7620	-3	4	7
8	1290.3328	-2	4	1304.5348	-9	3	1290.3163	4	3	1304.5734	-2	3	8
9	1289.4646	-2	2	1305.3379	-2	3	1289.4470	3	2	1305.3824	9	4	9
10	1288.5924	-7	3	1306.1380	12	7	1288.5744	2	3	1306.1880	21	17	10
11	1287.7179	2	3				1287.6993	11	3				11
12	1286.8384	-3	2	1307.7227	-5	2	1286.8195	5	2	1307.7842	-2	2	12
13	1285.9554	-7	3	1308.5106	-2	2	1285.9367	3	2	1308.5802	18	7	13
14	1285.0693	-7	4	1309.2937	-10	4	1285.0509	5	2	1309.3690	1	2	14
15	1284.1822	20	9	1310.0755	7	7	1284.1618	6	3	1310.1559	-1	2	15
16	1283.2863	-6	3	1310.8498	-15	7	1283.2688	2	3	1310.9396	0	2	16
17										1311.7196	-1	2	17
18	1281.4900	4	4	1312.3953	23	27	1281.4736	1	2	1312.4962	-2	2	18
19	1280.5850	-6	3	1313.1584	2	3	1280.5701	-9	5				19
20	1279.6758	-23	25	1313.9170	-27	11	1279.6655	2	26	1314.0399	7	6	20
21	1278.7664	-6	12	1314.6773	-2	2							21
22				1315.4321	6	4				1315.5682	2	2	22
23				1316.1836	19	11	1276.9289	7	6	1316.3269	-2	2	23
24	1276.0131	5	19	1316.9276	-6	3	1276.0131	37	19	1317.0831	3	2	24
25				1317.6713	4	3				1317.8352	3	2	25
26	1274.1612	25	11	1318.4098	-1	4	1274.1612	-7	11	1318.5828	-8	4	26
27	1273.2291	26	18	1319.1446	-5	3				1319.3290	3	2	27

28	1272.2907	-1	2	1319.8772	7	6							28
29				1320.6044	2	3	1271.3688	25	28	1320.8080	-4	5	29
30	1270.4102	13	6	1321.3263	-17	7	1270.4290	9	7	1321.5437	7	4	30
31	1269.4618	-9	6	1322.0478	-3	3	1269.4870	4	4				31
32	1268.5133	2	3	1322.7644	0	3	1268.5416	-3	3	1323.0012	-4	3	32
33	1267.5595	-4	3	1323.4770	1	2	1267.5936	-4	2	1323.7267	11	5	33
34	1266.6033	0	5	1324.1861	5	3	1266.6424	-6	5				34
35	1265.6441	9	7	1324.8905	0	3	1265.6874	-13	11				35
36										1325.8772	7	4	36
37	1263.7131	3	3	1326.2897	8	5	1263.7705	-3	8	1326.5894	30	26	37
38	1262.7420	-3	4	1326.9822	-2	4	1262.8079	8	4				38
39	1261.7687	2	3	1327.6719	-2	4	1261.8399	-4	3	1327.9974	18	9	39
40	1260.7920	8	3	1328.3580	0	3	1260.8699	-5	4				40
41	1259.8098	-7	5	1329.0398	-2	3	1259.8967	-6	4				41
42	1258.8261	-3	3	1329.7177	-5	4	1258.9218	6	4	1330.0832	2	4	42
43	1257.8387	-1	3	1330.3931	5	3	1257.9415	-4	3	1330.7716	-1	3	43
44	1256.8478	-1	4	1331.0627	-5	4	1256.9593	-3	3	1331.4561	-8	5	44
45	1255.8538	3	4				1255.9736	-6	4	1332.1395	9	4	45
46	1254.8557	0	3	1332.3928	-1	3				1332.8166	-2	3	46
47				1333.0527	7	4	1253.9935	-7	4	1333.4911	-3	3	47
48	1252.8503	3	4	1333.7078	6	6	1252.9996	0	3	1334.1626	1	5	48
49	1251.8420	-1	4	1334.3594	8	5				1334.8298	-3	5	49
50	1250.8308	0	4				1251.0017	3	6	1335.4934	-8	5	50
51	1249.8126	-35	22	1335.6479	-19	10	1249.9982	4	3	1336.1547	0	4	51
52	1248.7976	-5	6							1336.8120	2	5	52
53	1247.7787	20	19	1336.9269	13	13	1247.9809	-8	8	1337.4650	-3	4	53
54				1337.5586	9	8	1246.9691	0	5	1338.1154	1	4	54
55	1245.7256	18	11	1338.1858	-2	5	1245.9561	25	15	1338.7617	-1	5	55
56	1244.6925	1	5	1338.8105	1	3	1244.9363	11	7	1339.4034	-14	7	56
57	1243.6566	-10	7	1339.4315	6	4	1243.9147	8	6	1340.0458	15	9	57
58				1340.0459	-17	10	1242.8897	1	5				58
59				1340.6594	-9	10	1241.8626	2	6	1341.3123	-6	8	59
60	1240.5334	2	4							1341.9402	-17	14	60
61										1342.5668	-7	12	61
62				1342.4746	-8	4	1238.7656	19	11	1343.1916	20	18	62
63				1343.0727	1	4	1237.7233	-18	27	1343.8093	11	8	63
64	1236.3218	10	8				1236.6846	9	6	1344.4243	9	7	64

65	1235.2571	-24	16	1344.2557	3	6	1235.6394	-1	6	1345.0327	-24	19	65
66	1234.1945	-3	5	1344.8421	11	10	1234.5909	-16	15	1345.6433	0	6	66
67	1233.1267	-1	5	1345.4225	-1	7				1346.2483	2	6	67
68	1232.0559	3	10				1232.4885	-17	14	1346.8491	-4	6	68
69	1230.9810	0	20	1346.5732	-10	6	1231.4355	6	6	1347.4470	-5	10	69
70				1347.1452	11	13	1230.3768	-1	4	1348.0418	-2	8	70
71				1347.7097	-4	6	1229.3156	-6	10	1348.6331	-1	7	71
72	1227.7378	1	7	1348.2738	16	18	1228.2550	22	22	1349.2222	13	13	72
73	1226.6493	-7	12				1227.1868	0	5	1349.8049	-3	13	73
74	1225.5553	-37	16	1349.3823	-22	23	1226.1190	9	12	1350.3861	-1	10	74
75													75
76				1350.4825	13	16				1351.5375	-6	12	76
77				1351.0241	5	17	1222.8963	-1	12	1352.1100	10	10	77
78													78
79	1220.0552	0	18	1352.0965	-1	13							79
80				1352.6249	-22	28				1353.8019	2	10	80
81				1353.1549	12	17							81
82													82
83	1215.5982	48	24				1216.3828	-18	30				83
84				1354.7108	11	14							84
85							1214.1926	-17	27				85
86							1213.0942	-14	14				86

	1310 e - 1110 e 446						1310 f - 1110 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
1													1
2													2
3													3
4				1170.1337	16	14							4
5	1161.7829	28	25				1161.7829	-22	25	1171.0095	-15	14	5
6													6
7													7

8				1173.4909	22	12				1173.5673	-13	12	8
9													9
10							1157.6687	-29	25	1175.2818	-15	14	10
11	1156.7971	-3	13	1176.0114	-1	16				1176.1429	-5	7	11
12							1156.0416	14	20	1177.0066	11	20	12
13							1155.2269	-6	11	1177.8713	19	26	13
14	1154.3135	-4	16	1178.5377	-9	19	1154.4167	0	12	1178.7354	3	9	14
15	1153.4897	25	28										15
16	1152.6607	-4	10				1152.8016	4	9				16
17	1151.8377	22	20	1181.0699	3	6	1151.9982	19	23	1181.3411	-20	22	17
18	1151.0098	-7	11							1182.2161	1	11	18
19	1150.1850	-10	14	1182.7592	4	17	1150.3910	-14	20	1183.0925	19	20	19
20	1149.3623	2	6				1149.5947	14	17	1183.9656	-14	20	20
21	1148.5390	4	7				1148.7966	5	9	1184.8462	12	15	21
22	1147.7141	-16	17	1185.2941	-10	12	1148.0004	-4	7	1185.7254	7	11	22
23	1146.8941	9	24				1147.2075	1	7	1186.6048	-12	17	23
24	1146.0708	-5	10										24
25	1145.2489	-9	12	1187.8354	15	19	1145.6259	-1	13				25
26	1144.4282	-5	11	1188.6802	-4	6	1144.8380	-1	7				26
27	1143.6089	8	13	1189.5258	-17	27	1144.0519	0	9	1190.1480	10	12	27
28	1142.7901	22	25	1190.3752	7	15	1143.2673	-2	6				28
29				1191.2226	9	14	1142.4861	12	23				29
30				1192.0690	1	9				1192.8212	28	24	30
31				1192.9146	-17	18							31
32													32
33				1194.6106	-5	7	1139.3701	-11	13				33
34				1195.4589	3	8				1196.3990	-4	10	34
35				1196.3067	7	15	1137.8220	-21	21	1197.2966	-12	19	35
36				1197.1527	-6	10	1137.0536	7	10				36
37	1135.4246	21	21	1198.0005	-1	16							37
38				1198.8484	7	16							38
39	1133.7899	9	10	1199.6936	-11	17	1134.7489	6	10	1200.9027	-1	6	39
40				1200.5418	2	13	1133.9847	18	22	1201.8063	-4	8	40
41				1201.3904	22	23	1133.2178	-11	19	1202.7136	21	26	41
42				1202.2338	-8	18				1203.6157	-15	19	42
43	1130.5251	7	11	1203.0816	8	12	1131.6931	-18	17	1204.5257	19	21	43
44				1203.9261	-5	18				1205.4312	1	8	44

45										1206.3393	1	7	45
46				1205.6150	-23	24				1207.2489	9	11	46
47	1127.2595	-25	17	1206.4625	4	8	1128.6621	7	27	1208.1552	-23	29	47
48	1126.4463	-3	9	1207.3069	4	9							48
49													49
50							1126.3977	1	9	1210.8878	-12	14	50
51				1209.8369	-1	8				1211.7997	-6	15	51
52	1123.1822	-30	21										52
53										1213.6246	6	10	53
54				1212.3616	-10	17							54
55	1120.7400	11	18				1122.6421	1	14	1215.4483	-1	10	55
56													56
57	1119.1109	33	29										57
58	1118.2917	0	29				1120.3980	14	26				58
59													59
60							1118.9008	-10	20				60

	1330 e - 0330 e 446						1330 f - 0330 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
3				1305.1428	4	4				1305.1428	4	4	3
4	1298.4248	6	4	1305.9690	9	6	1298.4248	6	4	1305.9690	9	6	4
5	1297.5719	15	16	1306.7899	-7	11	1297.5719	15	16	1306.7899	-7	11	5
6	1296.7136	0	3				1296.7136	0	3				6
7	1295.8537	1	4	1308.4249	-15	13	1295.8537	1	4	1308.4249	-15	13	7
8	1294.9906	1	3	1309.2396	1	4	1294.9906	1	3	1309.2396	1	4	8
9	1294.1241	-3	4				1294.1241	-3	4				9
10	1293.2549	-3	5				1293.2549	-3	5				10
11	1292.3828	-1	4	1311.6602	2	4	1292.3828	-1	4	1311.6602	2	4	11
12				1312.4602	-3	4				1312.4602	-3	4	12
13	1290.6295	4	5	1313.2583	4	4	1290.6295	4	5	1313.2583	4	4	13
14	1289.7473	-3	3	1314.0518	-3	5	1289.7473	-3	3	1314.0518	-3	5	14
15	1288.8630	0	3	1314.8427	-4	4	1288.8630	0	3	1314.8427	-4	4	15

16	1287.9752	-2	3	1315.6308	-2	3	1287.9752	-2	3	1315.6308	-2	3	16
17	1287.0845	-3	4	1316.4156	0	3	1287.0845	-3	4	1316.4156	-1	3	17
18				1317.1971	-1	4				1317.1971	-1	4	18
19	1285.2957	13	13	1317.9753	-2	3	1285.2957	13	13	1317.9753	-2	3	19
20	1284.3946	0	3	1318.7506	0	3	1284.3946	0	3	1318.7506	-1	3	20
21	1283.4918	-1	3	1319.5229	3	3	1283.4918	0	3	1319.5229	3	3	21
22	1282.5861	0	3	1320.2912	-2	10	1282.5861	1	3	1320.2912	-2	10	22
23	1281.6771	-2	4	1321.0567	-3	4	1281.6771	-1	4	1321.0567	-4	4	23
24	1280.7653	-2	4	1321.8206	12	7	1280.7653	-1	4	1321.8206	11	7	24
25	1279.8500	-7	8	1322.5787	1	3	1279.8500	-6	8	1322.5787	0	3	25
26	1278.9332	3	5	1323.3349	2	4	1278.9332	5	5	1323.3349	1	4	26
27	1278.0122	0	3	1324.0866	-9	8	1278.0122	3	3	1324.0866	-11	8	27
28	1277.0899	15	11	1324.8374	2	3	1277.0899	18	11	1324.8374	1	3	28
29	1276.1615	-2	3	1325.5856	20	17	1276.1615	1	3	1325.5856	18	17	29
30	1275.2316	-4	4	1326.3266	-3	4	1275.2316	0	4	1326.3266	-5	4	30
31	1274.2989	-5	4	1327.0680	10	7	1274.2989	0	4	1327.0680	8	7	31
32	1273.3642	4	5	1327.8038	0	3	1273.3642	10	5	1327.8038	-3	3	32
33	1272.4252	-1	4	1328.5376	1	3	1272.4252	6	4	1328.5376	-2	3	33
34	1271.4832	-6	4	1329.2677	-2	8	1271.4832	2	4	1329.2677	-6	8	34
35	1270.5384	-11	5	1329.9952	0	4	1270.5384	-1	5	1329.9952	-5	4	35
36	1269.5912	-10	5	1330.7198	5	4	1269.5912	1	5	1330.7198	0	4	36
37				1331.4407	6	3				1331.4407	-1	3	37
38				1332.1580	2	3				1332.1580	-5	3	38
39	1266.7332	2	6	1332.8733	11	6	1266.7332	20	6	1332.8733	2	6	39
40	1265.7705	-36	13				1265.7705	-15	13	1333.5820	-24	22	40
41	1264.8135	11	21	1334.2918	3	4	1264.8135	35	21	1334.2918	-8	4	41
42	1263.8485	7	25	1334.9971	8	3	1263.8485	34	25	1334.9971	-5	3	42
43	1262.8790	-14	8	1335.6987	8	3	1262.8790	17	8	1335.6987	-7	3	43
44	1261.9094	-7	7	1336.3973	10	4	1261.9094	28	7	1336.3973	-7	4	44
45	1260.9343	-28	10	1337.0924	9	4	1260.9343	13	10	1337.0924	-10	4	45
46	1259.9601	-11	9	1337.7844	10	3	1259.9601	35	9	1337.7844	-13	3	46
47	1258.9798	-27	13	1338.4732	10	5	1258.9798	26	13	1338.4732	-15	5	47
48	1257.9979	-31	13	1339.1577	0	19	1257.9979	28	13	1339.1577	-29	19	48
49	1257.0134	-33	16	1339.8422	22	10	1257,0134	33	16	1339.8422	-11	10	49
50	1256.0260	-37	21	1340.5212	21	6	1256.0260	38	21	1340.5212	-17	6	50
51	1255.0371	-28	26	1341.1974	24	8	1255.0371	56	26	1341.1974	-19	8	51
52	1254.0493	19	28	1341.8700	23	6	1254.0372	-8	28	1341.8700	-25	6	52

53	1253.0452	-69	23	1342.5402	31	8	1253.0452	35	23	1342.5402	-23	8	53
54	1252.0545	4	16	1343.2050	17	15	1252.0436	11	5	1343.2050	-44	15	54
55				1343.8675	12	10	1251.0404	-1	15	1343.8675	-57	10	55
56				1344.5266	6	30	1250.0381	24	7	1344.5266	-72	30	56
57	1249.0465	24	15	1345.1841	16	14	1249.0270	-11	11				57
58	1248.0342	-12	4	1345.8354	-4	16	1248.0174	-4	8				58
59	1247.0258	18	13	1346.4859	1	5	1247.0046	0	6				59
60							1245.9841	-46	8	1347.1455	7	8	60
61							1244.9695	-4	4	1347.7905	7	6	61
62	1243.9757	13	17				1243.9474	-10	9	1348.4331	15	8	62
63	1242.9527	1	4	1349.0523	-11	6	1242.9225	-17	8	1349.0715	12	5	63
64	1241.9292	9	8							1349.7060	0	6	64
65	1240.9032	17	17	1350.3155	-21	9	1240.8671	-3	6	1350.3394	9	8	65
66	1239.8742	21	16	1350.9430	-17	7				1350.9658	-22	25	66
67	1238.8414	11	5	1351.5668	-18	4				1351.5966	22	8	67
68	1237.8052	-7	19				1237.7600	-16	9	1352.2200	23	7	68
69				1352.8045	-19	16	1236.7209	1	8	1352.8395	15	8	69
70				1353.4181	-22	15	1235.6768	-5	7	1353.4576	23	8	70
71	1234.6896	15	6	1354.0294	-15	9	1234.6297	-14	8	1354.0713	18	7	71
72	1233.6454	14	12	1354.6372	-10	9				1354.6817	10	6	72
73	1232.5993	19	21	1355.2430	9	16				1355.2915	26	10	73
74				1355.8386	-40	9	1231.4735	-25	25	1355.8943	2	10	74
75				1356.4393	-4	10	1230.4194	5	24	1356.4954	-9	14	75
76							1229.3593	2	10				76
77	1228.3879	1	8	1357.6261	25	20				1357.6909	-9	9	77
78	1227.3284	-13	11	1358.2133	29	13	1227.2342	30	23	1358.2830	-22	9	78
79				1358.7956	18	13	1226.1642	10	17	1358.8710	-46	15	79
80	1225.2041	-24	17	1359.3783	47	20	1225.0952	27	14	1359.4585	-46	13	80
81	1224.1411	-5	9	1359.9561	62	13	1224.0214	23	16				81
82													82
83													83
84													84
85													85
86	1218.7825	-19	17										86

	0530 e - 0330 e 446						0530 f - 0330 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
3													3
4				1151.3541	-14	14				1151.3541	-14	14	4
5							1142.9392	26	23				5
6	1142.0998	-10	19	1153.0528	3	15	1142.0998	-10	19	1153.0528	3	15	6
7				1153.9033	6	16				1153.9033	6	16	7
8	1140.4311	-17	29	1154.7549	10	19	1140.4311	-17	29	1154.7549	10	19	8
9										1155.6088	25	19	9
10				1156.4604	8	10				1156.4604	7	10	10
11				1157.3134	-7	11				1157.3134	-7	11	11
12				1158.1709	12	21				1158.1709	12	21	12
13	1136.2829	0	15				1136.2829	-1	15				13
14	1135.4546	-19	14	1159.8838	-2	6	1135.4546	-19	14	1159.8838	-3	6	14
15													15
16	1133.8083	12	13	1161.6027	1	6	1133.8083	11	13	1161.6027	-1	6	16
17	1132.9839	-3	9	1162.4650	15	17	1132.9839	-4	9	1162.4650	13	17	17
18	1132.1615	-10	12	1163.3260	5	11	1132.1615	-12	12	1163.3260	3	11	18
19	1131.3421	1	8	1164.1881	-4	12	1131.3421	-1	8	1164.1881	-8	12	19
20	1130.5232	5	10	1165.0526	1	7	1130.5232	2	10	1165.0526	-5	7	20
21				1165.9193	17	14	1129.7032	-19	14	1165.9193	10	14	21
22	1128.8879	1	8	1166.7838	0	12	1128.8879	-5	8	1166.7838	-9	12	22
23	1128.0730	9	7	1167.6516	6	14	1128.0730	1	7	1167.6516	-5	14	23
24	1127.2589	12	9	1168.5198	6	9	1127.2589	2	9	1168.5198	-9	9	24
25	1126.4461	15	8	1169.3900	15	8	1126.4461	3	8	1169.3900	-3	8	25
26	1125.6336	10	6	1170.2599	12	13	1125.6336	-6	6	1170.2599	-12	13	26
27	1124.8230	11	8	1171.1308	8	11	1124.8230	-9	8	1171.1308	-22	11	27
28				1172.0037	14	9				1172.0037	-22	9	28
29	1123.2045	3	14	1172.8778	22	11	1123.2045	-27	14	1172.8778	-22	11	29
30	1122.3999	28	17	1173.7530	31	23	1122.3999	-10	17	1173.7530	-23	23	30
31	1121.5934	20	18	1174.6272	20	15	1121.5934	-26	18	1174.6272	-44	15	31
32	1120.7889	21	13										32
33	1119.9858	23	17				1119.9858	-45	17				33

J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
34				1177.2555	-12	29							34
35	1118.3806	1	9	1178.1354	-4	12	1118.3880	-22	9	1178.1508	20	16	35
36				1179.0155	-3	10	1117.5914	-9	26	1179.0333	23	17	36
37	1116.7817	-7	4	1179.8974	8	12				1179.9158	13	13	37
38				1180.7757	-26	23	1116.0028	17	15	1180.8025	33	23	38
39				1181.6597	-12	12				1181.6857	5	27	39
40	1114.3926	-16	19	1182.5453	10	20	1114.4148	-11	17	1182.5746	21	18	40
41	1113.5986	-19	15	1183.4275	-11	15	1113.6246	-11	18				41
42	1112.8057	-22	28	1184.3110	-26	15	1112.8385	14	10	1184.3547	38	21	42
43				1185.1972	-21	11	1112.0517	16	11				43
44	1111.2272	11	7	1186.0832	-26	9	1111.2648	1	7				44
45				1186.9721	-8	18	1110.4818	7	8	1187.0305	18	8	45
46													46
47										1188.8233	24	16	47
48				1189.6339	-42	21	1108.1427	20	23	1189.7224	31	11	48
49	1107.2892	-9	10							1190.6204	12	14	49
50							1106.5872	-24	21				50
51	1105.7224	-1	9							1192.4249	12	12	51
52	1104.9416	15	27	1193.1978	-10	6							52
53	1104.1566	-18	28							1194.2370	22	14	53
54													54
55													55
56													56
57										1197.8751	-31	10	57
58				1198.5531	48	24				1198.7923	-15	26	58
59				1199.4495	95	22							59

	2110 e - 1110 e 446						2110 f - 1110 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
1													1
2	1283.9148	-2	21				1283.9148	31	21				2
3	1283.0712	-24	9				1283.0712	20	9				3

4	1282.2261	-29	13	1289.7141	0	5	1282.2261	24	13	1289.7289	7	5	4
5	1281.3782	-30	14				1281.3782	28	14	1290.5491	17	16	5
6	1280.5284	-18	23	1291.3388	-29	26	1280.5284	42	23				6
7	1279.6711	-48	18	1292.1508	1	4	1279.6711	10	18	1292.1785	14	3	7
8	1278.8157	-27	13	1292.9555	-8	3	1278.8157	26	13	1292.9874	-2	5	8
9	1277.9548	-40	12	1293.7595	8	7	1277.9548	15	12	1293.7956	5	2	9
10				1294.5581	3	4	1277.0901	-5	6	1294.6003	6	3	10
11	1276.2257	-12	4	1295.[illegible]538	1	3	1276.2257	7	4	1295.4004	-10	9	11
12	1275.3562	-5	5	1296.1458	-4	3	1275.3562	-5	5	1296.2007	6	3	12
13	1274.4838	5	9	1296.9364	9	6	1274.4838	-16	9				13
14	1273.6091	24	21	1297.7210	-5	3	1273.6091	-23	21	1297.7893	5	3	14
15				1298.5035	-8	3				1298.5799	12	5	15
16	1271.8447	6	6	1299.2836	-1	2							16
17	1270.9583	3	3	1300.0597	-2	2	1270.9721	-2	3	1300.1515	16	9	17
18	1270.0687	-1	2	1300.8314	-14	7	1270.0866	-4	3				18
19	1269.1764	-1	5	1301.6025	1	2	1269.1989	-1	2	1301.7073	-20	23	19
20	1268.2821	11	6	1302.3686	-1	2	1268.3081	0	2	1302.4849	3	4	20
21	1267.3826	1	2	1303.1321	4	2	1267.4144	-1	2	1303.2567	-3	3	21
22	1266.4805	-3	2	1303.8915	0	3	1266.5184	2	3	1304.0263	-2	2	22
23	1265.5753	-7	4	1304.6478	-1	3	1265.6188	-3	5	1304.7931	0	2	23
24	1264.6684	3	5	1305.4007	-4	3	1264.7173	0	8				24
25	1263.7571	0	3	1306.1513	3	3				1306.3173	-2	2	25
26	1262.8432	2	2							1307.0752	-2	2	26
27	1261.9259	0	2	1307.6412	3	4				1307.8304	0	2	27
28	1261.0055	-2	3				1261.0840	11	9	1308.5804	-21	9	28
29	1260.0825	0	3							1309.3315	-2	2	29
30	1259.1564	2	3	1309.8501	-10	20	1259.2495	-2	3	1310.0756	-25	19	30
31							1258.3309	17	14	1310.8220	4	3	31
32	1257.2956	11	11	1311.3082	0	6	1257.4069	9	6	1311.5623	1	3	32
33				1312.0313	-5	4	1256.4799	-3	3	1312.2997	-3	2	33
34	1255.4221	14	10	1312.7522	0	4	1255.5519	1	2	1313.0356	6	4	34
35				1313.4710	17	10	1254.6215	6	4	1313.7671	0	3	35
36				1314.1826	-5	4	1253.6872	-2	2	1314.4960	-4	3	36
37				1314.8935	-2	3	1252.7514	1	2	1315.2227	-2	4	37
38	1251.6369	-4	4	1315.6012	2	3	1251.8131	3	2				38
39	1250.6834	-7	5	1316.3052	2	3	1250.8719	2	2				39
40	1249.7265	-14	8				1249.9281	-1	2	1317.3871	14	16	40

41	1248.7686	-2	2	1317.7035	1	3	1248.9836	14	8	1318.1006	-5	3	41
42	1247.8077	9	4	1318.3978	1	5	1248.0339	1	3	1318.8142	4	4	42
43	1246.8421	2	3	1319.0889	1	3	1247.0831	2	3	1319.5231	-6	4	43
44	1245.8736	-5	3	1319.7767	1	3	1246.1293	-3	3	1320.2313	4	3	44
45	1244.9032	-2	2	1320.4616	3	3				1320.9373	19	17	45
46	1243.9298	-1	3	1321.1426	-1	3	1244.2186	26	25	1321.6369	-3	4	46
47	1242.9530	-5	3	1321.8206	-3	3				1322.3361	-3	3	47
48	1241.9745	2	4	1322.4954	-5	5	1242.2932	1	3	1323.0329	0	4	48
49	1240.9928	5	3				1241.3282	0	4	1323.7270	3	2	49
50	1240.0075	0	3	1323.8372	9	6	1240.3609	-1	4				50
51	1239.0201	2	3	1324.5029	11	4	1239.3917	1	5	1325.1058	-8	12	51
52	1238.0308	13	9				1238.4179	-21	22	1325.7937	10	6	52
53	1237.0370	6	4	1325.8244	12	8				1326.4774	12	7	53
54	1236.0400	-5	7	1326.4784	-7	5	1236.4705	2	6	1327.1577	5	8	54
55	1235.0422	2	11	1327.1314	-6	5	1235.4911	-11	7	1327.8353	-4	4	55
56	1234.0415	8	5	1327.7830	13	12	1234.5115	-6	6	1328.5127	11	11	56
57	1233.0383	15	7				1233.5290	-9	8	1329.1853	1	4	57
58	1232.0304	2	4	1329.0708	-9	6	1232.5462	6	6	1329.8552	-10	8	58
59							1231.5591	-3	5				59
60	1230.0095	4	5	1330.3478	-16	10	1230.5710	-2	5	1331.1921	9	7	60
61	1228.9945	-1	5	1330.9836	0	5				1331.8536	-15	9	61
62							1228.5895	4	7	1332.5169	2	4	62
63	1226.9577	-3	5							1333.1763	3	5	63
64	1225.9360	2	5				1226.5993	-2	5				64
65	1224.9108	-4	4	1333.4904	2	5	1225.6007	-12	15	1334.4861	-18	14	65
66	1223.8837	-4	5				1224.6023	-4	5	1335.1402	-2	5	66
67	1222.8544	-1	6				1223.6032	15	12	1335.7909	0	6	67
68	1221.8210	-14	8				1222.5996	5	6				68
69				1335.9486	-2	6	1221.5944	-4	5				69
70	1219.7522	11	18	1336.5573	12	11	1220.5898	8	9	1337.7293	-1	4	70
71	1218.7115	-3	8	1337.1607	1	12	1219.5817	1	6				71
72	1217.6706	3	10				1218.5707	-20	14	1339.0126	10	11	72
73	1216.6273	9	15	1338.3618	11	18	1217.5629	6	8	1339.6497	0	6	73
74	1215.5794	-8	8				1216.5500	-6	14				74
75				1339.5491	-5	8							75
76				1340.1390	-8	6							76
77	1212.4268	-14	10				1213.5067	-6	12	1342.1832	-5	9	77

78	1211.3733	1	8	1341.3119	0	4	1212.4904	0	9				78
79							1211.4727	4	10				79
80				1342.4752	21	12							80
81	1208.1936	-18	22										81
82	1207.1329	9	12										82
83	1206.0677	11	9										83
84	1204.9988	-5	14	1344.7637	1	24	1206.3676	10	14				84

	1420 e - 0420 e 446						1420 f - 0420 f 446						
J	P Obs	O-C	Unc	R Obs	O-C	Unc	P Obs	O-C	Unc	R Obs	O-C	Unc	J
2				1302.9701	-19	11				1302.9701	-19	11	2
3	1297.9334	3	17	1303.7990	-6	11	1297.9334	2	17	1303.7990	-6	11	3
4	1297.0839	27	19										4
5													5
6													6
7	1294.5063	18	15	1307.0751	-2	4	1294.5063	16	15	1307.0751	0	4	7
8				1307.8853	-1	5				1307.8853	1	5	8
9	1292.7694	1	7	1308.6918	-3	6	1292.7694	-4	7	1308.6918	0	6	9
10	1291.8975	10	7	1309.4950	-3	5	1291.8975	3	7	1309.4950	1	5	10
11	1291.0205	3	4	1310.2947	-2	4	1291.0205	-7	4	1310.2947	2	4	11
12	1290.1409	4	6	1311.0905	-6	5	1290.1409	-9	6	1311.0905	0	5	12
13	1289.2581	9	4	1311.8831	-6	7	1289.2581	-8	4	1311.8831	0	7	13
14	1288.3696	-9	28	1312.6736	8	12	1288.3696	-31	28	1312.6736	16	12	14
15	1287.4819	16	4				1287.4819	-11	4				15
16	1286.5909	43	30	1314.2394	-9	11	1286.5909	9	30	1314.2394	0	11	16
17	1285.6924	30	7	1315.0185	-3	8	1285.6924	-12	7	1315.0185	7	8	17
18	1284.7888	2	8	1315.7933	-4	9				1315.7933	7	9	18
19				1316.5644	-7	6	1283.8895	-11	5	1316.5644	5	6	19
20	1282.9797	30	26	1317.3323	-6	4				1317.3323	7	4	20
21										1318.0996	38	20	21
22							1281.1608	-?	16				22
23	1280.2328	3	14				1280.2440		4				23

24	1279.3139	32	16	1320.3677	-6	5				1320.3677	8	5	24
25	1278.3865	11	3	1321.1176	-6	5				1321.1176	9	5	25
26				1321.8654	10	11	1277.4742	-5	4	1321.8654	24	11	26
27				1322.6058	-13	25	1276.5451	3	4	1322.6058	1	25	27
28	1275.5873	-9	7				1275.6123	7	4				28
29				1324.0820	4	16	1274.6781	29	22	1324.0820	16	16	29
30	1273.7060	2	7	1324.8134	0	7	1273.7356	2	6	1324.8134	11	7	30
31				1325.5410	-6	8	1272.7927	3	6	1325.5410	4	8	31
32	1271.8085	-3	8	1326.2661	-1	7	1271.8451	-10	6	1326.2661	8	7	32
33	1270.8548	-9	5				1270.8958	-8	2				33
34	1269.8979	-7	5	1327.7038	-6	6	1269.9440	3	4	1327.7038	-1	6	34
35	1268.9374	-6	4	1328.4185	5	15	1268.9886	9	3	1328.4185	7	15	35
36	1267.9743	4	9	1329.1278	-2	6	1268.0290	6	5	1329.1278	-2	6	36
37	1267.0064	2	6	1329.8346	3	6	1267.0668	9	4	1329.8346	0	6	37
38	1266.0346	-5	5				1266.1008	6	6				38
39	1265.0601	-4	4	1331.2368	8	10	1265.1323	11	7	1331.2368	-2	10	39
40	1264.0826	2	7	1331.9313	0	7	1264.1582	-9	3	1331.9313	-14	7	40
41	1263.1001	-7	7	1332.6227	-3	14	1263.1842	5	4	1332.6227	-21	14	41
42				1333.3119	9	6	1262.2057	5	5	1333.3119	-14	6	42
43	1261.1275	0	6	1333.9966	12	7	1261.2233	-2	7	1333.9966	-15	7	43
44				1334.6777	17	11	1260.2413	26	26	1334.6777	-16	11	44
45	1259.1408	3	9	1335.3562	32	17	1259.2498	-8	4	1335.3562	-6	17	45
46	1258.1422	2	7	1336.0290	27	18				1336.0290	-18	18	46
47				1336.6950	-10	20							47
48	1256.1342	-9	11	1337.3619	0	7	1256.2676	-1	7				48
49	1255.1306	38	22				1255.2681	10	6				49
50	1254.1178	25	10				1254.2642	8	7	1338.6887	-17	23	50
51	1253.1020	13	7	1339.3358	-19	12	1253.2556	-10	7	1339.3486	23	14	51
52	1252.0865	35	21	1339.9875	-14	8	1252.2522	55	11	1340.0004	18	8	52
53							1251.2347	9	10				53
54	1250.0383	-2	8										54
55				1341.9205	1	17							55
56	1247.9805	-20	20				1248.1773	9	11				56
57	1246.9487	-16	9				1247.1510	-2	9				57
58	1245.9156	1	6							1343.8421	34	23	58
59	1244.8786	5	19	1344.4443	2	14				1344.4673	6	11	59
60				1345.0630	-28	18				1345.0913	0	14	60

61	1345.6811	-27	13	1243.0185	-16	13	1345.7136	11	8	61
62							1346.3312	7	7	62
63	1346.9099	13	8	1240.9360	-7	7	1346.9464	11	19	63
64				1239.8899	-6	5	1347.5547	-22	8	64
65	1348.1187	1	11	1238.8413	-1	7				65
66										66
67										67
68				1235.6770	2	6				68
69										69
70										70
71				1232.4882	16	11				71
72				1231.4174	-2	15				72
73										73
74				1229.2723	7	17				74
75				1228.1939	-6	15				